Mechanisms of attention for cues associated with rewarding and aversive outcomes

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Declaration

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

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ABSTRACT

Attentional biases arising from classical conditioning processes may contribute to the maintenance of drug addictions and anxiety disorders. This thesis examined whether attentional mechanisms for conditioned stimuli (CS) would be dominated by affective properties (Lang, Greenwald, Bradley, & Hamm, 1993), or the uncertainty of the stimulus in predicting the outcome (Pearce & Hall, 1980). In chapter one affective and uncertainty-driven mechanisms of attention are discussed in relation to rewarding and aversive outcomes. In experimental chapter 2 methodological issues are addressed. In experimental chapters three and four attentional mechanisms are tested using a discriminative conditioning procedure with visual stimuli of varying predictive certainty (CS+,CS+/-,CS-) for a monetary or noise outcome (US). Attention was measured using an eye-tracker, and emotional conditioning and learning were measured using Likert scales. It was found that attention was mediated by uncertainty (chapter 3), but increasing the intensity of the outcome switched attention to affective-driven mechanisms for the noise outcome (chapter 4). In a further experiment this effect on attention remained for the noise outcome even under conditions promoting uncertainty-driven mechanisms (chapter 6). When cigarettes were the unconditioned stimuli instead of money in the appetitive conditioning, attention was also mediated by stimulus affect (chapter 5). In chapter 7 the data are discussed and it is concluded that when the outcome is highly emotionally salient, affective-driven mechanisms of attention dominate over uncertainty.

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1. General Introduction

1.1 Drug addiction, anxiety disorders, and classical conditioning

Worldwide drug use is estimated to include 2 billion alcohol users, 1.3 billion smokers and 185 million illicit drug users (WHO, 2002). Drug addiction is a chronic relapsing disorder, characterized by compulsive drug-taking and drug-seeking behaviours despite negative consequences (O'Brien & McLellan, 1996). Relapse (a return to drug-seeking behaviour after a period of abstinence) represents one of the most important processes in addiction because if drug-taking does not resume, homeostatic mechanisms are thought to return to a pre-drug state, and many of the effects of drug use may then fade with time (LeBlanc, Kalant, Gibbins, & Berman, 1969). Most available treatments for relapse are relatively ineffective (Van den Oever, Spijker, Smit, & De Vries, 2009), probably due to the lack of knowledge regarding the exact neurobiological underpinnings of relapse. Some relapse triggering factors include the presence of the drug in the body, stress, and reactivity to sensory cues associated with drug-taking (Yahyavi-Firouz-Abadi & See, 2009). The focus of this thesis will be on elucidating cue-induced mechanisms of drug-taking, adding to our understanding of relapse and thus supporting the development of therapeutic interventions to prevent relapse.

Anxiety disorders represent the most common type of mental disorder across a range of countries (Demyttenaere et al., 2004), yet these patients often do not receive as much attention as those with other mental disorders (Kroenke, Spitzer, Williams, Monahan, & Lowe, 2007). In addition, anxiety disorders are frequently co-morbid with depressive disorders, leading to a longer duration of psychiatric symptoms and poorer psychosocial ability (Hirschfeld, 2001). Anxiety disorders are also often co-morbid with heavy alcohol use, smoking and addiction problems (Martin-Merino, Ruigomez, Wallander, Johansson, & Garcia-Rodriguez). Indeed, some authors have proposed that drug addictions develop in response to anxiety disorders such as phobias (Compton, Cottler, Phelps, Ben Abdallah, & Spitznagel, 2000), indicating anxiety as a risk factor in the development of drug abuse. As with drug addictions, reactions to sensory cues have often been associated in the maintenance of some anxiety disorders (Lang, Davis, & Ohman, 2000), although in this case the cue is related to an anxious or threatening event rather than drug-taking. As the maintenance of both anxiety disorders and addictions may be mediated by the associations of sensory cues of threatening and incentive events respectively, it is important to elucidate to what extent these cues may be involved in the maintenance of such disorders. I will argue that through processes of classical conditioning, sensory cues will acquire aversive (anxiety) or appetitive (drugs) properties, and that attentional biases to these cues persist even after conditioning has occurred, possibly implicating such attentional biases in the maintenance of addictions and anxiety disorders.

Main model of classical conditioning

Cues signalling rewards and aversive events are thought to initiate affective responses due to classical conditioning processes. Classical conditioning describes the phenomenon whereby a previously neutral stimulus (conditioned stimulus, CS) when reliably and repeatedly preceding an unconditioned stimulus, comes to mimic the same response that the unconditioned stimulus elicits (unconditioned response, UR), which is known as the conditioned response (CR) (R. A. Rescorla, 1967).

Classical conditioning depends upon several key principles including contingency, surprise, and expectation. While the contiguous relationship between the CS and the US (how temporally close together in time they are) may be important in conditioning, it is more important that they are contingent upon each other, i.e. that the US is more likely to occur after presentation of the CS, than if the CS is not present (R. A. Rescorla, 1968). In addition, the CS must tell the organism something new about the likelihood of the occurrence of the US in order for conditioning to occur. If the US is fully predictable on the basis of other CSs present, then conditioning will not occur for a new CS paired contingently with the US (Kamin, 1969). According to the most prominent theory of classical conditioning (R.A. Rescorla & Wagner, 1972), in order for conditioning to occur the US must be surprising to some extent. This engages the animal to search for correlates of the US. Stimuli (CSs) that reliably predict the US, elicit an expectation of the US, such that an organism is not surprised by its occurrence.

Conditioned appetitive responses

Cues that become associated with rewards may come to elicit conditioned responses that are the same as responses elicited by the rewards themselves. A conditioned stimulus paired with an appetitive reinforcer, such as food, will elicit approach behaviour (Williams & Williams, 1969). This control of behaviour appears to be dependent on the CS-US association regardless of the consequences of such behaviour as pigeons will approach and peck a key paired with food even when making this response leads to omission of the reinforcer (Williams & Williams, 1969). In humans it is more difficult to elicit conditioned appetitive responses for natural nondrug rewards, except when the stimuli are highly arousing. However, the literature on classical conditioning with erotic stimuli has provided some indication that conditioned stimuli will elicit appetitive responses. (Stark, Klucken, & Kagerer, 2009) reported that when a geometric figure was paired with an erotic image (CS+) it elicited enhanced ratings of pleasantness compared to a stimulus paired with a nonerotic image.

The drug addiction literature is more replete with examples of how stimuli paired with a rewarding outcome may elicit appetitive responses in both animals and humans. One method used extensively in animals in order to measure the reward value of drugs is the conditioning place preference (CPP) paradigm. In this procedure rodents are repeatedly placed in two distinctively different compartments, joined together but separated by a partition; they always receive a drug injection before being placed in one compartment, and a saline injection before being placed in the other compartment. After several pairings, the partition between compartments is removed; hence the animals can enter and remain in each box according to preference. The proportion of time that animals spend in the drug-paired compartment is considered to be an index of the reward value of the drug. In most CPP research, investigators assume that the context CS becomes associated with the drug US through a Pavlovian conditioning process (Bardo & Bevins, 2000). Animals show a conditioned place preference (CPP) for compartments associated with a variety of drugs including opiates (Hand, Stinus, & Le Moal, 1989), nicotine (Fudala & Iwamoto, 1986), and cocaine (Shippenberg & Heidbreder, 1995). While it has been assumed that CPP appears to reflect a preference for a context due to the contiguous association between the context and a drug stimulus, this assumption has been criticised. It has been suggested that the apparent preference for an environment previously paired with a drug reward may not be related to Pavlovian conditioning. Instead, preference may be induced by the novelty of experiencing that side of the compartment in a drug-free state (Schechter & Calcagnetti, 1993). However, studies that have included a novel context as a control have demonstrated a preference for the drug-paired context relative to the novel context (Mucha & Iversen, 1984), thus negating any novelty explanation. Furthermore, (Risinger & Oakes, 1995) reported that at low doses (0.5 mg/kg) nicotine induced conditioned place preferences, while at higher doses (2.0 mg/kg) it induced conditioned place aversion (CPA). Thus, the ability of the context to become associated with both aversive and appetitive properties of drugs represents an additional problem for the novelty explanation.

In humans, preferences have also been found for CSs previously paired with drugs. For example, cocaine abusers will choose to experience a CS+ previously paired with cocaine compared to a CS- paired with placebo (Foltin & Haney, 2000), while smokers will attend more to a stimulus paired with smoking (CS+) than a stimulus unpaired with smoking (CS-) (Mucha, Pauli, & Angrilli, 1998). Thus, in both animals and humans, stimuli paired with drugs will elicit appetitive conditioned responses in the same way as natural rewards such as approaching the stimulus, attending to the stimulus, and choosing to experience the stimulus in preference to stimuli not paired with the drug.

Pavlovian conditioned stimuli activate an appetitive motivational system

Instrumental responding in the presence of appetitive conditioned stimuli indicates that the conditioned stimulus activates an appetitive motivational system. However, conditioned motivated instrumental responding could be related to a specific representation of a reward, or it may reflect activation of a central appetitive motivational system that is not related to a specific outcome expectancy (Dickinson & Balleine, 1994). In support of the specific-outcome hypothesis, stimuli associated with a drug come to elicit the same physiological responses as the drug itself. Smoking cues elicit increases in heart rate and skin conductance (Tiffany & Drobes, 1990), consistent with the unconditioned effects of cigarettes, while alcohol cues elicit increases in salivation rate (Szegedi et al., 2000) and heart rate (Glautier, Drummond, & Remington, 1992), and cocaine cues induce increases in heart rate (Ehrman, Robbins, Childress, & Obrien, 1992) - comparable to the unconditioned effects of the drug itself. However, these results could also be interpreted as supporting a model of general motivational activation as such increases in the aforementioned physiological responding are also related to general appetitive responses. For example, both cocaine cues (Ehrman et al., 1992) and cigarette cues (Tiffany & Drobes, 1990) induce increases in heart rate responses. One way in which outcome-specific and general motvational systems have been separated is through a paradigm known as Pavlovian-to-instrumental transfer. Appetitive PIT describes an associative learning phenomena whereby a Pavlovian cue associated with a reward, activates a positive motivational state that may enhance instrumental responding for the same reward (outcome-specific PIT) or for any reward (general PIT) (J. Hall, Parkinson, Connor, Dickinson, & Everitt, 2001). As the classical conditioning procedure and the instrumental response procedure are trained separately, if the subsequent presence of the conditioned stimulus increases instrumental responding, then this indicates initiation of either a representation of the outcome, or that general motivational processes have been activated. If the Pavlovian cue selectively enhances instrumental responding for the specific reward it was paired with and doesn’t enhance instrumental responding for a different reward, then this supports appetitive responding as a product of a specific CS-US representation. However, if the cue does increase responding for different rewards then the theory that the cue engages a general motivational system, dissociated from any specific CS-US representation, is supported. Hogarth, Dickinson, Wright, Kouvaraki, & Duka (2007) conducted a study with humans whereby a conditioned stimulus paired with a monetary outcome, and a conditioned stimulus paired with a cigarette outcome, selectively invigorated instrumental responding for the response that matched the outcome. This shows that the conditioned stimulus activated a specific outcome expectancy rather than a general motivational appetitive state. However, for some drug rewards there is evidence that they may activate a general motivational state rather than a specific outcome expectancy. (Glasner, Overmier, & Balleine, 2005), in contrast, reported that in rats cues associated with alcohol enhanced responding for a food reward (polysucrose**)** as well as invigorating responding for alcohol. These contradictory findings indicate that conditioned appetitive motivational responses for some rewards may be outcome specific, whereas for other rewards, the appetitive responses are a product of activation of a general appetitive motivational system.

The role of cognitive expectancy in Pavlovian reward learning

Several investigators have suggested that cognitive factors mediate the subjective, physiological and behavioural responses to drug cues (Marlatt, 1985). Outcome expectancies regarding the drug (subjective expectations of what will happen if a drug is taken) have been shown to modify physiological and behavioural responses to drug cues. For example, Brandon, Wetter, & Baker (1996) reported that enhanced craving and smoking behaviour in the presence of smoking cues was mediated by positive outcome expectancies for cigarette smoking. Perceptions of cigarette availability also moderate responses to smoking cues. Droungas, Ehrman, Childress, & O'Brien (1995) reported than smoking cues only elicited increases in cigarette craving if subjects thought they could smoke after the cue exposure session; if subjects thought they could not smoke after the session craving was not enhanced in the presence of smoking cues. Hogarth, Dickinson, Hutton, Elbers, & Duka (2006) found that only those that became contingency-aware (as measured by self-reported expectancy ratings) of a CS-cigarette association elicited conditioned responses in the presence of the CS+ as compared to the presence of a CS-. Conditioned responses included enhanced pleasure (as measured through subjective ratings) and increased attentional bias (as measured via saccadic eye movements). Collectively, these studies demonstrate that cue-elicited behaviour is related to a conscious expectancy of the US.

However, other findings have indicated that for certain types of rewarding stimuli, such as food or drink, conditioned responses can occur, even in the absence of contingency awareness. For example, when one group had a novel flavoured drink (CS) paired with caffeine (US) while another group did not, the caffeine group indicated enhanced liking for the drink while the unpaired group did not (Yeomans, Spetch, & Rogers, 1998). None of the subjects reported awareness that they had been consuming caffeine. This type of learning may be a special type of associative learning known as "evaluative" learning. Evaluative learning refers to changes in the liking of a stimulus that result from pairing that stimulus with either a positive or negative valenced stimulus (De Houwer, Thomas, & Baeyens, 2001). However, while the acquisition of Pavlovian conditioning and evaluative conditioning involve a similar process it appears the underlying processes may be very different. Other studies have found that flavours paired with sugar elicited higher hedonic evaluations even though participants couldn't reliably report which flavours had been paired with sugar (Dickinson & Brown, 2007), thus supporting Yeomans et al.'s (1998) finding that flavour evaluative conditioning is not mediated by contingency knowledge.

Conditioned fear responses

As with conditioned rewards, stimuli paired with an unconditioned aversive event, acquire the ability to mimic responses that the unconditioned stimulus usually initiates. Hermann, Ziegler, Birbaumer, & Flor (2002) found that a neutral stimulus paired with an aversive odour elicited enhanced physiological responses such as increased skin conductance and startle response, which are consistent with the unconditioned effects of an aversive stimulus. In addition, valence-specific responses that characterize an aversive motivational system (eg. species-specific freezing and avoidance behaviours) are initiated by stimuli associated with an aversive outcome. Conditioned place aversion (CPA) is akin to the conditioned place preference paradigm although the conditioned aversive response is measured as the proportion of time that animals spend in the threat-paired compartment, with a reduction in time spent in the compartment indexing the aversive value of the threat. Fanselow & Helmsetter (1988) reported that contexts paired with footshock elicited freezing behaviour consistent with defensive behaviours elicited by the footshock itself. The fear-potentiated startle (FPS) response is the enhanced response to a fearful auditory stimulus related to activation of a central state of fear (Davis, 1990). It is particularly useful for measuring conditioned fear, not only as it reflects activation of the central fear state, but because it is reflected in an enhancement rather than a suppression of behaviour (Davis, 1986). The amplitude of an acoustic startle response is increased in the presence of a fearful unconditioned stimulus (Lang, Bradley, & Cuthbert, 1992). and aversively conditioned stimuli also enhance startle responses in a similar manner (Falls & Davis, 1994), indicating that conditioned stimuli activate fear responses in the same way as the threat itself. .

Conditioned responses may also reflect defensive preparatory responses as a result of the expectancy of the US. The expectancy of an aversive stimulus, due to the presence of the conditioned stimulus, may sometimes initiate defensive emotional reactions. In one example, when a stimulus predicted that a painful shock would occur, subjects reported lower levels of anxiety, negative valence and pain intensity after receiving the shock compared to when they received shocks on trials where they were presented with a stimulus that was uncorrelated with shock (Carlsson et al., 2006). Thus, conditioned stimuli may initiate coping responses as well as responses associated with the US itself.

As well as eliciting coping or “passive avoidance” responses such as freezing, conditioned aversive stimuli appear to initiate instrumental avoidance responses, commonly referred to as “active avoidance” responses. Cain & Ledoux (2007) reported that animals trained to associate a rearing response with termination of a shock-paired CS, exhibited increased rearing in the presence of the CS previously paired with shock compared to a CS that had not been previously paired with shock.

The role of cognitive expectancy in Pavlovian fear learning

The conscious expectancy of a US in the presence of CS has also been shown to influence conditioned aversive responding. Only those that reported contingency awareness in an aversive shock conditioning paradigm demonstrated discriminative skin conductance responses in the presence of the CS+ (Dawson, 1973). In addition, when expectancy of shock is measured on a trial-by-trial basis (after CS presentation but before the shock is delivered) then discriminative SCRs only occur after subjects report a higher expectation of shock after CS+ presentation compared to following CS- presentation (Dawson & Biferno, 1973). Using images of snakes and spiders Ohman, Eriksson, Fredriksson, Hugdahl, & Olofsson (1974) found that higher skin conductance responses in the presence of the CS were accompanied by higher expectancy ratings. These findings indicate that conditioned responding is strongly related to an expectancy of the US.

While knowledge of the CS-US contingency is clearly important in order for the acquisition of a conditioned response, (Dawson & Biferno, 1973) found that while only those who demonstrated a conditioned SCR were contingency aware, some subjects reported contingency awareness in the absence of the SCR. This led to the formation of the "necessary gate hypothesis" (Dawson & Furedy, 1976), which states that conscious awareness of CS-US contingencies is a "necessary gate" that has to be achieved before conditioned responding can occur, but that this awareness was not sufficient – other factors are also involved.

Non-cognitive learning processes in conditioned fear

In contrast to cognitive theories of fear learning, there are other reports that emotional learning may occur in neural circuits distinct from cognitive conscious learning (J. E. Ledoux, 1993). Furthermore, Ohman (1993) proposed that this autonomic activation of fear systems by fear stimuli could occur prior to cognitive awareness, and may also subsequently bias cognitive expectancies. The somatic marker hypothesis (Damasio, 1996), which states that autonomic conditioned responses can assist in cognitive decision making processes, also postulates that emotional learning may occur separately and prior to conscious awareness of stimulus contingencies; negative outcome associations can be stored and retrieved nonconsiously in order to inform subsequent decision-making situations. Crucially, according to this theory *"marker signals arise in bioregulatory processes, including those which express themselves in emotions and feelings"* (Damasio, 1996, pp. 1413). These signals may be expressed covertly (eg. a behavioural response bias for an appetitive or aversive outcome) or overtly (eg. qualifying certain scenarios as dangerous or advantageous). However, it should be most reliably manifested in physiological responses such as enhanced skin conductance responses (Damasio, 1996). While Damasio's (1996) hypothesis relates to processes of reasoning and decision-making rather than conditioning per se, such concepts do seem to contradict the findings that conscious expectancy of an outcome is a requirement for conditioned responses to occur. Indeed, awareness may also only be a necessary factor for certain classes of conditioned responding. Hamm & Vaitl (1996) reported that subjects that were unaware that a stimulus predicted an aversive event still showed enhanced startle responses in the presence of the conditioned stimuli, while increased skin conductance in the presence of the CS+ only occurred for subjects who became explicitly aware of the stimulus contingencies. Eyeblink conditioned responses elicited through a CS paired with an aversive puff of air to the eye, may also be acquired independently of contingency awareness (Davey, 1987). Eyeblink and startle response may reflect reflexive defence mechanisms that don't require conscious expectancy of an outcome, while skin conductance responses may reflect activation of the CS-US representation. That said, under certain experimental conditions, it may be possible for discriminatory skin conductance responses to occur in the absence of explicit awareness, and this argument is outlined below.

Under certain experimental conditions it does seem possible for conditioned responses to occur in the absence of explicit knowledge of contingencies. The type of paradigm used to measure conditioned responding may have an effect on whether responding is reliant on contingency awareness. Trace and delay procedures of conditioning, in particular, tend to mediate whether or not awareness is necessary for conditioned responding to occur. In delay conditioning the conditioned stimulus and the unconditioned stimulus are presented at the same time; in trace conditioning there is a temporal delay between the termination of the conditioned stimulus and onset of the unconditioned stimulus. Employing the delay procedure, Knight, Nguyen, & Bandettini (2003) reported that a tone paired with an aversive white noise elicited discriminative SCRs, even when the tone was presented below the perceptual threshold of awareness and subjects did not report an expectancy of the US. In contrast, when there is a delay between the conditioned stimulus and the outcome, awareness of the contingencies appears to be required in order for conditioned responding to occur. Weike, Schupp, & Hamm (2007) conducted a conditioning paradigm using the trace procedure and found that increased skin conductance response and startle blink magnitude only occurred in the presence of the conditioned stimulus for participants that were contingency aware. As mentioned previously, startle blink magnitude has been associated with implicit learning, which appears to contradict this finding. However, Weike et al. (2007) found that in a delay version of the same conditioning paradigm, greater startle responses were elicited regardless of awareness.

Classical conditioning processes in drug addictions

In addiction, previously neutral environmental stimuli become associated with the properties of drugs as a result of being repeatedly paired with the pharmacological effects of the drugs. Drug-conditioned stimuli may contribute to drug-seeking behaviour and relapse as once detected they activate a representation of the drug, often expressed as "craving" for the drug. However, there are both affective and motivational aspects of the drug that could become associated with environmental stimuli.

According to positive reinforcement theories of addiction, it is the positive affective properties of the drug that become conditioned and controls behaviour. In this view drugs are addicting because they produce euphoria and positive affect (McAuliffe & Gordon, 1974). Evidence for this theory is reliant on theories where priming doses of a drug have enabled reinstatement of drug-taking behaviour (Dewit & Stewart, 1981, 1983), indicating that it is the presence of the drug in the body, rather than its absence, which activates appetitive motivational processes. Drug-seeking then occurs due to this activation of the appetitive motivation system. If the rewarding effects of the drug become conditioned to previously neutral stimuli this can lead to drug-seeking responses as the euphoria or positive affect induced by the presence of the drug-related stimuli elicits a positive motivational state leading to approach and consumption of the drug (Stewart, Dewit, & Eikelboom, 1984). Evidence that stimuli may become associated with the positive affective attributes of drug stimuli are obtained mainly from the place preference literature. In rats, an environment previously paired with experiencing the effects of amphetamine (Reicher & Holman, 1977), morphine (Sherman, Pickman, Rice, Liebeskind, & Holman, 1980), cocaine (Sticht, Mitsubata, Tucci, & Leri, 2009), heroin (Tyhon, Lakaye, Adamantidis, & Tirelli, 2008), and nicotine (Le Foll & Goldberg, 2005).

However, studies have shown that the subjective pleasurable effects of drugs may be dissociated from their motivational properties. According to this theory, rewarding stimuli (such as drugs) activate an incentive salience pathway (often conceptualised as a “wanting” pathway) as well as a separate pathway related to the hedonic affective properties (a “liking” pathway), and it is the incentive salience pathway that becomes sensitised over time due to repeated exposure to drugs and drug cues (Robinson & Berridge, 1993). This theory argues that it is the activation of the incentive salience pathway by drug cues that results in desire for the drug and drug-seeking behaviour. The neural substrate hypothesised to be involved in incentive salience is mesotelencephalic dopamine. Lesions that deplete dopamine from the nucleus accumbens and caudate nucleus don’t abolish hedonic evaluations of rewards, while they abolish the motivation to eat (Berridge, Venier, & Robinson, 1989). The application of dopamine agonists and antagonists also support a role for this pathway in incentive salience but not in sensory pleasure (Treit & Berridge, 1990). The incentive salience theory of addiction is an attractive one as it can explain how addicts will continue to self-administer drugs in the absence of any subjective pleasurable effects (Lamb et al., 1991).

In addition to stimulus-stimulus associations, some stimulus-response mechanisms have been implicated in the later stages of addiction. According to (Di Chiara, 1998), repeated exposure to drug reinforcers enhances DA release in the nucleus accumbens, which in turn strengthens both stimulus-response associations as well as stimulus-reward associations.

Thus, over time the ability of a stimulus to initiate an approach response in the absence of an expectancy of the outcome may become strengthened – this is often conceptualised as “habit” formation and may lead to compulsive drug-seeking. It is proposed that over time, goal-directed behaviours become dominated by reflexive processes in the control of drug-seeking responses (Robbins & Everitt, 2002). Certainly, studies on rats have shown that administering one drug of abuse, amphetamine, during lever-pressing for a food reward enhanced the transition from goal-directed to habit-forming control of behaviour (Nelson & Killcross, 2006). Thus, stimulus-response mechanisms may have more of a role in drug-seeking behaviours in the later stages of addiction.

Classical conditioning processes in anxiety disorders

There is also evidence of a role for conditioning processes in the development and maintenance of anxiety disorders. The assumption underlying most anxiety disorders is that anxiety disorders reflect the inappropriate activation of defence responses in response to fear-producing stimuli eg. hypervigilance, avoidance, increased autonomic activity) (J. E. LeDoux, 1995). One theory is that pathological fear to environmental stimuli could be due to enhanced ability for cues to become associated with an aversive event, and this is expressed in an enhanced conditioned response (Orr et al., 2000). In addition, delayed extinction of the conditioned response and generalisation of the conditioned fear response to other stimuli with similar features to the original conditioned stimulus has been proposed to play a role in the persistence of fear responses in anxiety disorders (Mineka & Zinbarg, 1996).

Specific phobias are proposed to be related to cued fear conditioning, as according to some evolutionary theories, certain threatening stimuli (eg. snakes, spiders) are pre-disposed to undergo superior conditioning and are more resistant to extinction than other stimuli (Ohman & Mineka, 2001). Thus the persistence of phobias may be related to these superior conditioning processes. Likewise, social phobia has been proposed as related to evolutionary preparedness-theory (the theory that certain stimuli are more pre-disposed to make associations) (Ohman, 1986). According to this view, threatening social stimuli such as angry faces undergo superior conditioning with an aversive event and is more resistant to extinction. Indeed, pairing of angry faces as compared to happy faces with an aversive outcome yields greater skin conductance responses (Ohman & Dimberg, 1978). However, other studies have demonstrated that in certain anxiety disorders it is the delayed extinction that may be the crucial factor rather than enhanced associability. In one study, social phobics demonstrated an enhanced resistance to extinction relative to controls in a conditioning procedure where a neutral face was paired with an aversive odour, but showed no difference in the acquisition of conditioned responses (Hermann et al., 2002). Furthermore, the social phobics exhibited an increased expectancy bias for the occurrence of the aversive outcome, indicating a possible mechanisms through which over-generalisation of the fear response to other cues may occur (Mineka & Zinbarg, 1996).

As previously mentioned, the fear-potentiated startle (FPS) response is the enhanced response to a fearful auditory stimulus, which reflects the activation of a central state of fear (Davis, 1990). Importantly, the FPS has also been used to demonstrate that contextual cues may become associated with aversive events. During one fear conditioning procedure, baseline startle responses were greater in the knowledge that they were going to undertake a fear conditioning paradigm, compared to procedures where the participants were aware that no aversive stimulus would be encountered (Bocker, Baas, Kenemans, & Verbaten, 2001). Several studies have reported that startle blink amplitude to specific cues predicting a threatening event were no different between controls and individuals with anxiety disorders, but baseline startle response amplitudes were greater for those with panic disorder (Grillon, Ameli, Goddard, Woods, & Davis, 1994) and PTSD (Grillon, Morgan, Davis, & Southwick, 1998). These findings suggest that in certain anxiety disorders generalised cues, but not specific cues, may mediate fear responses. Certainly, some anxiety responses such as hyper-vigilance and persistent free-floating anxiety may be triggered by context or generalised conditioning processes rather than a specific cue, while generalisation of acquired fear from one conditioned stimulus to another may underlie generalised aversive anticipation e.g. as in PTSD and panic disorder.

While the classical conditioning model can clearly account for many of the phenomena in anxiety disorders, there have been criticisms of this model. One major criticism has been that in specific phobias some people report no memory for the original aversive encounter with the phobic stimulus (Menzies & Clarke, 1993b). Even if it is assumed that the original event is forgotten, it still doesn’t explain how the event is forgotten yet the emotional response is remembered. However, it is possible that over time a stimulus-response mechanism dominates over cognitive mechanisms. Indeed, there are separate pathways that may be activated by the conditioned stimulus, and one of these pathways goes directly from the sensory thalamus to the amygdala (J. LeDoux, 1996). Thus, it is plausible that a conditioned stimulus may initiate an emotional fear response in the absence of cognitive awareness. Some non-conditioning models of phobias have proposed that specific phobias develop when intrinsic fears (species-specific) do not habituate due to the absence of safe exposure, or dishabituation in the presence of life stresses (Menzies & Clarke, 1995). While such theories may explain the failure in recalling the original conditioning event, there appears to be no published reports investigating the hypothesis that phobic individuals have had a lack of safe exposure or life stresses prior to phobia onset relative to non-phobic individuals. That said, the role of nonassociative processes may have more of a role in some specific phobias such as height and water phobias (Menzies & Clarke, 1993a, 1993b).

Summary

Throughout the thesis I will argue that responses elicited by conditioned stimuli predictive of an appetitive or an aversive outcome are a result of the CS eliciting an expectation of the outcome. Thus, conditioned appetitive or conditioned aversive responses should only be present in those who are aware of the stimulus contingencies. That said, in aversive conditioning there is the possibility that conditioned responses may reflect two different types of conditioned responses – one being activated by the fear system and related to avoidance, and the other activated by anxiety and related to vigilance. These two systems may initiate different types of conditioned responses. Although other separations of conditioned responses were discussed (eg. conditioned responses relating to affective or motivational properties), this separation was not important to the current investigation. However, the separation of affective and motivational conditioned responses may be alluded to when relevant.

1.2 Attentional biases in addiction and anxiety

Attentional biases in the etiology and maintenance of drug addiction

Increased attention to drug cues seems to characterise many addictions including nicotine dependence (Gross, Jarvik, & Rosenblatt, 1993), cocaine dependence (Rosse et al., 1997), alcohol dependence (Townshend & Duka, 2001), and opiate dependence (Lubman, Peters, Mogg, Bradley, & Deakin, 2000). Increased attention is also related to increased craving for cocaine in cocaine addicts (Copersino et al., 2004), while for alcoholics increased attention to alcohol cues has been shown to be related to increased likelihood of relapse (Cox, Hogan, Kristian, & Race, 2002). The role of attention to drug cues in mediating drug-seeking behaviours is clearly an important pathway that requires further clarification.

Enhanced attention to drug cues could be mediated by the pleasurable or incentive properties of the drugs, as outlined by Stewart et al. (1984) and Robinson and Berridge (1993). Both theories of addiction postulate a role for the capture of attention by drug-associated cues. However, other models of attention have elaborated on these theories to suggest how different aspects of attention may be modulated by drug cues. In addition to the automatic allocation of attention, (Franken, 2003) proposed that attention was maintained for longer on drug cues as well as being oriented to faster. According to this model there is an initial orientation of attention towards a stimulus from the perception that it is drug-relevant, attention is then maintained allowing relapse to occur through several possible pathways: the perception of the cue will trigger craving; it will enhance further processing of the cues which could increase drug-related cognitions leading to craving; the attention to the cue will limit resources to other cues related to coping mechanisms or control strategies. Elaborating on the attentional aspects of this model Ryan (2002) proposed that cue reactivity is preceded by preattentive evaluation of potential drug cues, whereby if the stimuli are deemed drug-relevant selective attention is recruited allowing deeper appraisal of the stimuli. Thus, while the majority of theories propose a role for the initial capture of attention, Ryan's (2002) model of attention to drug cues argues that drug cues are processed preattentively, while Franken (2003) advocates that attention is also maintained after initial capture, and this may be relevant to drug-seeking and relapse.

Increased attentional bias to drug cues may induce drug-seeking responses via the capture of attention. According to some theories this may be related to a specific representation of the drug and an expectancy of it's positive reinforcing effects (Stewart et al., 1984), or the capture of attention may activate drug-seeking behaviours via a non-cognitive, automatic pathway that is unrelated to drug expectancies and drug-seeking responses (Tiffany, 1990). According to this latter theory, reactions to drug cues only induce strategic cognitive processes and subjective desire for the drug when the automatic processing of drug cues is somehow impeded or interrupted. However, attentional biases for drug stimuli are often coupled with desire for the drug, indicative of a relationship between the two. Schizophrenics have deficits concerning their ability to selectively allocate their attentional resources as demonstrated in abnormal facilitated reaction times in colour/word Stroop tasks (Barch, Carter, Hachten, Usher, & Cohen, 1999). Thus, they may be a useful population to explore how mechanisms of attention may be related to the activation of drug-wanting. Indeed, Copersino et al. (2004) found that non-schizophrenic cocaine-dependents showed greater interference from cocaine words on a Stroop task than schizophrenic cocaine dependent subjects. Non-schizophrenics also reported greater desire for cocaine than schizophrenics and their desire ratings correlated with the level of interference for cocaine-related words. Thus, the lower levels of craving in schizophrenics may be related to reduced attentional biases for the cocaine stimuli. If attentional biases do induce drug-wanting then this strongly implicates a role for attention in drug-seeking behaviours. Certainly, desire for the drug has been shown to precipitate relapse in smokers (Bagot, Heishman, & Moolchan, 2007; Killen & Fortmann, 1997), in alcoholics (Wrase et al., 2008), cocaine addicts (Rohsenow, Martin, Eaton, & Monti, 2007), and in heroin abuse (Llorente del Pozo, Fernandez Gomez, Gutierrez Fraile, & Vielva Perez, 1998). In order to further elucidate the causal relationship between attention, drug-wanting, and drug-seeking, Field & Eastwood (2005) manipulated the direction of attention such that in a group of heavy social drinkers attention was trained either to attend to alcohol stimuli or to not attend to it by use of a dot-probe task. The group that were trained to attend to the alcohol stimuli showed an enhanced attentional bias for the alcohol stimuli, reported higher urges to drink and consumed more alcohol compared to the group that were not trained to attend to the stimuli. In a similar paradigm with smokers and smoking stimuli, those trained to attend to the smoking stimuli exhibited enhanced attentional biases for the smoking stimuli and increased urges to smoke (Attwood, O'Sullivan, Leonards, Mackintosh, & Munafo, 2008). Those trained to avoid the smoking stimuli didn’t exhibit attentional biases for these stimuli and reported decreased urges to smoke. Thus, one of the major routes through which attentional biases may induce relapse behaviour is via activation of the desire for the drug.

Attentional biases in anxiety disorders

The core tenet of cognitive theories of anxiety is that maladaptive responses to internal and external stimuli occur as a result of a biased interpretation of stimuli as dangerous or threatening (Beck & Rush, 1985; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

Processing of a stimulus may incorporate several stages and Beck and Clark (1997) proposed an information processing model of anxiety that involved several separate schemas. To paraphrase, these stages of processing consist of *"a) the initial registration of a threat stimulus; b) the activation of a primal threat mode; and c) the secondary activation of more elaborative and reflective modes of thinking"* (pp.49). Attention may play a role in each of these stages as initial registration requires orienting towards the stimulus, activation of a threat mode may cause hypervigilance for threat cues and a narrowing of attention, and elaborative modes of thinking may lead to avoidance of the stimulus as a coping strategy. Attentional biases for threatening information also characterize a range of anxiety disorders including generalised anxiety disorder (Mathews & MacLeod, 1985), social phobia (Hope, Rapee, Heimberg, & Dombeck, 1990), panic disorder (R. J. McNally et al., 1994), posttraumatic stress disorder (Kaspi, Mcnally, & Amir, 1995), and obsessive-compulsive disorder (Foa, Ilai, Mccarthy, Shoyer, & Murdock, 1993). Attentional biases are clearly an important mediating factor in anxiety and have been further elaborated upon in other cognitive models of anxiety. In the Mathews & Mackintosh (1998) model of anxiety, they postulate that in all individuals there are inhibitory links between attention to current tasks and attention to novel, potentially threatening, stimulus input. Potentially threatening stimuli are processed via a threat evaluation system (TES), which strengthens activation of threat-related attributes. Thus, when activation of this system reaches a particular threshold attention will be re-allocated from on-going tasks to the threatening stimulus. They hypothesise that it is this system that becomes oversensitized in high trait anxiety individuals, causing them to appraise incoming stimuli more readily as highly threatening. It is also this inability to ignore threatening stimuli that may be a key factor in initiating and maintaining maladaptive responses to fearful stimuli. In the context of classical conditioning, the higher sensitivity to threat may lead to an increased likelihood that stimuli associated with a fearful event will capture attention and consequently initiate conditioned fear responses and avoidance behaviours.

According to theories of social phobia (Rapee & Heimberg, 1997) attentional resources are allocated not only to an internal representation of how the individual appears to an "audience", but also onto any perceived threat in the social environment. As regards this latter attentional process (Rapee & Heimberg, 1997) suggest that vigilance for negative external social cues may be both a significant component of social anxiety disorder in itself, and serve as an input into attention on internal representations of the self as seen by others. Thus, attention to threatening stimuli is also an important mediator in social anxiety disorders.

Facilitated engagement of threat may lead to heightened awareness of threat in the environment and subsequently the initiation of anxiety states, while impaired disengagement of threat may lead to elaborated processing of threatening stimuli, thus maintaining anxiety states. In addition, attention according to the vigilance-avoidance hypothesis (threat stimuli are initially attended to and then avoided) may prevent habituation and emotional processing of the threat, such that the individual always regards the stimulus as threatening and anxiety is maintained (Mogg, Mathews, & Weinman, 1987). In addition to a role in the maintenance of anxiety disorders, attentional biases have been proposed as a causal mechanism in anxiety. Macleod, Rutherford, Campbell, Ebsworthy, & Holker (2002b) employed a dot-probe task to demonstrate that inducing attentional biases towards threatening stimuli enhanced emotional vulnerability to a stressor. The dot probe task was modified so that neutral and negative emotional words were presented as a pair, and after they disappeared a probe appeared in the place of one of the words, and participants had to make a discriminative response as to the identity of the probe. Latency to respond to the probe reflected the engagement of attention. Half of the participants always had the probe replace the threat word, and half had the probe replace the neutral word. Both sets of participants were then subjected to a task designed to induce stress and completed mood analogue scales to measure their negative mood state. Those who were cued to attend to the threatening stimuli showed an enhanced attentional bias to these stimuli, and also had higher negative mood after the stress test compared to those cues to avoid the threatening information. Consequently, the findings from this study appear to suggest that attentional biases may have a causal role in inducing anxiety states.

Summary

Attentional biases appear to be a stable feature of anxiety disorders and addictions and may even play a role in maintaining them. The mechanisms of attention through which these biases may exert their control is important to clarify, and is discussed in the following section.

1.3 Incentive theories of attention

By examining the mechanisms through which incentive stimuli may capture attention, a greater understanding may be reached regarding how rewarding drug stimuli and threatening stimuli play a role in pathological disorders and maladaptive behaviours. Evolutionary models of emotion and attention state that stimuli related to rewards or threats are preferentially attended to due to their biological significance for the survival of an organism (Gray, 1990). This enhanced capture of attention facilitates further processing of the stimulus, subsequently facilitating the appropriate approach or avoidance response (Lang & Davis, 2006). Bindra's (1969) theory of emotion and motivation in learning, states that both appetitive and aversive stimuli elicit an appropriate central motivational state (appetitive and aversive respectively). Subsequently, activation of the central motivational state *"consists of neural changes that favor selective attention to a certain class of incentive stimuli"* (Bindra, 1969, pp. 1081). However, there is some discrepancy over the mechanism through which selective attention is mediated. Emotionality may be conceptualised as being composed of both valence and arousal dimensions (Witvliet & Vrana, 1995). Some theories argue that, regardless of the valence, it is the arousal elicited by the stimulus that attracts attention, while other theories state that it is the hedonic value (pleasant or unpleasant) that engages attention. These two theories of incentive-driven attention are outlined below.

Valence-specific theories of attention

Theories purporting that the valence of a stimulus attracts attention generally favour a negativity bias account. According to negativity bias models of attention, threatening stimuli attract attention more readily than rewarding stimuli because threatening stimuli are more crucial to survival than rewarding stimuli (Pratto & John, 1991). This automatic evaluation of valence does not categorize according to level of negativity, such that equal attention should be accorded to mild negative and strong negative stimuli. There is some evidence in support of a negativity bias as attentional biases have been reported for unpleasant over pleasant stimuli (E. Fox et al., 2000; Hajcak & Olvet, 2008). However, arousal levels were not matched for pleasant and unpleasant stimuli in these studies, and as discussed below, higher arousal levels for negative stimuli may have biased attention. Negativity bias theories also report that attentional biases occur pre-attentively, outside of awareness (Ohman & Soares, 1998; Pratto & John, 1991). Certainly, there is evidence that highly threatening stimuli such as snake and spider stimuli may be detected even when stimuli are presented below the threshold of awareness (Ohman & Soares, 1998). Regardless of such evidence, this theory still cannot explain why rewarding stimuli are preferentially attended to over neutral stimuli.

In contrast to the negativity bias theories, some theories have proposed a positivity bias exists for affective stimuli. The “positivity bias” theory states that “normal”, nondepressed individuals hold biases towards pleasant information resulting in deeper evaluation, encoding and memory for pleasant in contrast to unpleasant and neutral stimuli (Deldin, Keller, Gergen, & Miller, 2001; Matt, Vazquez, & Campbell, 1992). However, in contrast to the literature in support of negativity biases, very few studies have reported a greater attentional bias for positive stimuli compared to negative stimuli.

Arousal theories of attention

According to motivational theories of attention, activation of either an appetitive or an aversive motivational system signals that a stimulus should be attended to (M. M. Bradley, 2009). Lang, Bradley, & Cuthbert (1997) proposed that it is the arousal response elicited by the presence of appetitive or aversive stimuli that acts as the indicator of the presence of a motivationally-relevant event, and that subsequently engages attention for the event. Scherer’s (2001) sequential evaluation check (SEC) model also states that arousal serves as an initial relevance check, signalling that attentional resources should be allocated to enhance further processing. Certainly, there is evidence that autonomic arousal is related to activation of motivational systems - in the presence of affective stimuli self-reported interest ratings, self-reports of arousal and measures of autonomic arousal (skin conductance responses) were all related, while autonomic measures were not related to ratings of stimulus valence (Lang, Greenwald, Bradley, & Hamm, 1993). Furthermore, there is evidence that such arousal mechanisms are related to attention, as participants have been reported to choose to attend to highly arousing erotic and mutilation images for longer compared to less arousing pleasant and unpleasant images (Lang et al., 1993). Similar findings have been reported employing reaction times in a dual-task paradigm as the measure of attention. Longer reaction times in response to a cognitive task were obtained in the presence of highly arousing stimuli compared to low arousal stimuli, regardless of stimulus valence (Buodo, Sarlo, & Palomba, 2002). Greater P300 amplitudes have also been reported in the presence of highly arousing pleasant and unpleasant stimuli relative to low arousing stimuli (Schupp, Junghofer, Weike, & Hamm, 2003). Thus, in studies where a negativity bias has been reported, it is likely that greater attention for the aversive images was confounded by a greater arousal for negative stimuli. Indeed, when highly arousing erotic stimuli has been used, an attentional bias is sometimes reported for such stimuli over threatening stimuli (Aquino & Arnell, 2007). Intuitively, the arousal theory of attention is more appealing than the negativity bias theories as both rewards and threats are important for an organism's survival.

Summary

The incentive properties of stimuli have been shown to capture attention for both aversive and appetitive events. There are various theories surrounding whether attention is related to hedonic affective properties (like, dislike) or the motivational/arousing (approach, avoid) properties of these stimuli. That said, the majority of evidence appears to favour the concept that attention is related to the motivational attributes of stimuli. Although the current focus of the investigation will not be to separate these two mechanisms, the effects of these components on attention will need to be taken into account when eliminating possible confounds.

1.4 Separating the components of attention in rewards and punishments

According to models of selective attention there are three consecutive stages: 1) an initial shift of attention to the stimulus, 2) engaging attention with the stimulus, 3) disengaging attention from the stimulus (M. I. Posner, 1980). Attentional biases for affective stimuli may be related to one or all of these stages. However, which component is important in addictions and anxiety disorders differs between theories. A further separation of attention may be conceptualised as relating to automatic (or exogenous) and controlled (or endogenous) mechanisms of attention. According to one definition of these concepts, automatic processes occur without intention, do not interfere with other mental processes and cannot be controlled, while controlled processes interferes with other processes and requires intention and awareness (M. I. Posner, & Snyder, C., 1975). In general, attention at stimulus presentations of 50-200ms is associated with automatic shifts in attention, while above that time period attention is related to the conscious control of attention (Allport, 1989). In order to separate the different components of attention electroencephalography (EEG) studies will often be alluded to. Brain activity elicited at certain time points after stimulus presentation maybe differentially related to these different components. The P1 and subsequent N1 produced at 100-200ms after stimulus onset and are sensitive to physical stimulus factors and index early sensory processing within the extrastriate visual cortex (Olofsson, Nordin, Sequeira, & Polich, 2008). The P300 and late positive potential (LPP) reflect positive electrophysiological activity occurring from 300ms after stimulus onset. They are influenced by task-relevance, motivational significance and arousal level (Polich & Kok, 1995), indicating they are related to selective voluntary attention processes. Thus, P1 and N1 components are most likely related to the automatic capture of attention, while the P300 and LPP are related to controlled processes associated with engaging attention.

Evidence for attentional biases to affective stimuli is presented below, with a specific focus on separating these different components. I will argue that due to the substantial evidence indicating that affective stimuli capture attention, and possibly impair the disengagement of attention, conditioned stimuli associated with an affective outcome will induce similar effects.

Attention to non-drug rewards

Evidence is mixed regarding whether or not rewarding stimuli engage attention automatically, although it is likely that these mixed results are due to differences in the arousal level of the stimuli used. For example, (Kissler, Herbert, Winkler, & Junghofer, 2009) reported no differences in P1 and N1 amplitudes between pleasant and neutral words stimuli.However, pleasant word stimuli may not be particularly arousing, and this may account for the lack of an attentional bias. For example, even at stimulus presentation as short as 120ms (Schupp, Junghofer, Weike, & Hamm, 2004) and 200ms (Herbert, Junghofer, & Kissler, 2008b) highly arousing erotic stimuli enhanced N1 amplitudes compared to neutral stimuli, indicating that when pleasant stimuli are more arousing they capture attention automatically.

More consistent findings are reported for attentional biases associated with the later voluntary mechanisms of attention. Certainly, several different measures of attention (electrophysiological, reaction times, eye movements) appear to support the concept that rewarding stimuli engage attention. The P300 component is enhanced in the presence of highly motivating erotic images compared to neutral images (Briggs & Martin, 2009), indicating that pleasant stimuli engage attention voluntarily. In addition, increases in LPP amplitudes, are also enhanced for positive affective stimuli relative to neutral stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Herbert, Junghofer, & Kissler, 2008a). In support of the electrophysiological data, studies using overt measures of attention report similar findings. Using eye-movements as a measure of attention, one study demonstrated that positive stimuli engaged attention for longer time periods than non-affective stimuli. In this study, when positive picture scenes were presented as a pair with neutral picture scenes and viewed for 3 seconds subjects initial fixation durations were longer for positive compared to neutral pictures (Caseras, Gamer, Bradley, & Mogg, 2007). Another overt measure of attention may be obtained through reaction times in the dot-probe task. In the dot-probe task participants are presented with a stimulus pair for a set period of time, and when the stimuli disappear a dot appears in the location of one of the stimulus pairs. Faster reaction times in response to the dot indicate enhanced attention for the preceding stimulus. Using the dot-probe task Bradley, Mogg, White, Groom, & de Bono (1999) found that happy faces presented as a pair with neutral faces at 500ms and 1250ms did not elicit enhanced reaction times for probes in the place of the happy faces, implying that happy faces did not engage voluntary mechanisms of attention. The inconsistency with this finding and with other findings indicating a sustained attentional bias for positive stimuli, may again be related to variations in the arousing properties of the stimuli used. Indeed, studies using erotic images, which are considered highly arousing, tend to elicit attentional bias effects (Briggs & Martin, 2008; Cuthbert et al., 2000; Herbert et al., 2008a), while studies that use less arousing stimuli such as happy expressions elicit less consistent attentional biases (B. P. Bradley, Mogg, Falla, & Hamilton, 1998; Lipp, Price, & Tellegen, 2009). These differences imply that arousal level rather than valence may be the affective component that drives the voluntary engagement of attention. As previously mentioned, the arousing properties of stimuli may be related to their motivational value (Lang et al., 1997), implying that stimuli with a greater motivational value enhance attention via increased autonomic arousal. In support of this view, enhancing the motivational value of a rewarding event through the manipulation of internal drive states, increases attentional biases to the same reward. In one dot-probe task, attention for a food stimulus presented for 500 ms was increased when the value of the food was increased via hunger manipulation (Mogg, Bradley, Hyare, & Lee, 1998b).

There is less report that positive affective stimuli induce impaired disengagement of attention, although there is evidence that this phenomena does occur under some circumstances. Attentional disengagement for affective outcomes may be measured in a cueing paradigm using the invalid trials (the target and the cue are in opposite spatial locations) - the reaction time costs of responding to a target following an invalid affective cue compared to responding to a target following an invalid neutral cue acts as the measure of disengagement. Using this paradigm, attention was greater for cues indicating point gain (rewarding cues) relative to neutral cues, indicating greater impaired disengagement for positively-valenced cues. However, this effect was only found for individuals scoring high on an extraversion scale, while those scoring high on an introversion scale did not show this effect (Derryberry & Reed, 1994). In contrast, when using a similar paradigm but with emotional faces as the cues, reaction times for targets replacing invalid positive cues were no different for targets replacing invalid negative cues (E. Fox, Russo, Bowles, & Dutton, 2001b). Thus, it appears that appetitive stimuli do not impair the disengagement component of attention, except for individuals who are extremely attracted to rewards.

Attention to drug rewards

The Stroop task has been one of the most predominant methods of assessing automatic attentional biases to drug stimuli. Typically, the colour-naming latency of drug-relevant words is assumed to reflect the extent to which processing resources are automatically allocated to the drug stimuli relative to colour-naming latency for non-drug words. A variety of drug dependents have shown this interference effect from modified Stroop tasks, including smokers (Johnsen, Thayer, Laberg, & Asbjornsen, 1997), heroin addicts (Franken, Kroon, Wiers, & Jansen, 2000), and alcoholics (Stormark, Laberg, Nordby, & Hugdahl, 2000), implying that the automatic capture of drug-relevant stimuli is a key feature in addiction. Caution should be taken, however, when using data from the Stroop task as evidence for an automatic bias for drug stimuli, as there is some disagreement over whether the task reflects the automatic component of attention alone, or whether it reflects several components of attention (C. M. Macleod, 1991). That said, tasks using different measures have indicated that drug stimuli do capture attention at very short stimulus durations. In particular, studies using dot-probe tasks with stimuli presented for brief time periods have yielded promising results. Stormark, Field, Hugdahl, & Horowitz (1997) presented abstinent alcoholics with alcohol stimuli for 100ms, and Morgan, Rees, & Curran (2008) presented frequent ketamine-users with ketatmine stimuli for 200ms, and both groups indicated faster reaction times for the probes replacing drug stimuli.

There is mixed evidence concerning whether or not drug cues also engage attention for drugs stimuli after they have been initially detected (eg. at stimulus presentations >200 ms). In an extension of the Morgan et al. (2008) study, stimuli were also presented for 2000ms. At this stimulus duration there was no apparent attentional bias for drug stimuli in the frequent ketamine users, implying that while drug stimuli may capture attention, attention is not necessarily maintained. In contrast Bradley, Field, Mogg, & De Houwer (2004) reported that when measuring attention using the dot-probe task, smokers but not non-smokers exhibited an attentional bias for smoking stimuli at both 200ms and 2000ms, indicating a bias in both the capture and maintenance of attention. This discrepancy may be due to a number of factors including different pharmacological properties, previous experience with drug cues, and the extent of drug dependence. Drug dependence (and hence motivation to obtain the drug) may manipulate later conscious components of attention. This could explain the lack of attention in ketamine users as they were not dependent on the drug (C. J. Morgan et al., 2008), while smokers were considered nicotine-dependent in the Bradley et al. (2004) study. In support of this theory, heavier or more dependent drug users (for whom drug stimuli should be more motivationally salient) have consistently demonstrated greater biases associated with the voluntary engagement of attention. Indeed, Townshend & Duka (2001) and Field, Mogg, Zetteler, & Bradley (2004) reported that when using the dot-probe task, reaction times for targets replacing alcohol stimuli (presented for 500ms and 2000ms respectively) were faster for heavy social drinkers compared to light social drinkers.

While there is a multitude of evidence indicating attentional biases for drug stimuli at long stimulus durations, whether this is due to engagement or disengagement processes, has not yet been fully elucidated. The majority of studies exploring attentional biases in drug addiction have employed the dot-probe and Stroop paradigms, which don't differentiate between the engagement and disengagement components of attention. Thus, it is impossible at present to conclude whether drug stimuli impair attentional disengagement.

Attention to threats in non-anxious individuals

Some theories state that the detection of threatening stimuli is automatic and drives attention, as such a mechanism may be beneficial for the survival of an organism if they have to make extremely fast escape responses (Ohman, Flykt, & Esteves, 2001; West, Anderson, & Pratt, 2009). As with appetitive stimuli, aversive stimuli presented for short periods of time (<200ms) appear to elicit attentional biases, signifying that attention is automatically captured by aversive stimuli. (Bannerman, Milders, de Gelder, & Sahraie, 2009) demonstrated that saccadic orienting was faster for faces and bodies displaying fearful emotion than for stimuli displaying neutral emotions when stimuli were presented at 20ms. The modified Stroop (using threatening or unpleasant words or images) has also been used to demonstrate that threatening stimuli automatically capture attention. In one example, (Lee, Lim, Lee, Kim, & Choi, 2009) used facial stimuli that had been previously paired with a mild electric shock and measured reaction times to identify the colour of the facial stimuli. Faces that had been paired with shock increased colour-naming reaction times relative to faces that had not been paired with shock. However, as previously noted, the Stroop task has been criticised for not reflecting a pure measure of automatic attention (C. M. Macleod, 1991).

After initial detection of an aversive stimulus, there are various contrasting theories regarding the subsequent maintenance of attention. Some theories argue that attention is maintained in order to enhance evaluation of a stimulus (Mogg, Bradley, de Bono, & Painter, 1997), which in the context of a potentially threatening stimulus may be important in decision-making processes regarding “fight-or-flight” responses. In contrast, the vigilance-avoidance theory proposes that while threatening stimuli will initially be attended to (attentional vigilance), they will subsequently be avoided in order to alleviate the negative mood state induced by such stimuli (Mogg et al., 1987). The dot-probe paradigm is a useful task in resolving this discrepancy as manipulation of stimulus duration may be used to measure the engagement of attention at various stages of processing (eg. initial orienting versus maintained attention). Using this task Cooper & Langton (2006) reported that reaction times were only enhanced for angry faces relative to neutral faces, when presented at 100ms but not for 500ms, indicating that while attention was captured by threatening stimuli, it was not maintained. Likewise, Bannerman et al. (2009) reported that saccadic orienting for stimulus pairs was faster for faces and bodies displaying fearful emotions than for similar stimuli displaying neutral emotions at 20ms but not at 500ms. Thus, while it does appear that threatening stimuli attract attention, attention may be withdrawn after initial detection and encoding of stimuli. However, neither of these studies reported that threat stimuli were avoided (i.e. attentional biases at 500ms were equal for neutral and aversive stimuli), which is problematic for the vigilance-avoidance hypothesis.

In contrast, Yiend & Mathews (2001), reported that threatening stimuli were avoided as evidenced through increased reaction times on trials when the target and the threat cue were in the same spatial location relative to when the cue was neutral. However, these discrepancies may be due to differences in the type of stimuli used. Bannerman et al. (2009) and Cooper and Langton (2006) used fearful and angry faces respectively, which may have been less threatening than the images used in the Yiend and Mathews (2001) study. The stimuli used in this latter study included weapons and dangerous animals, which may induce a greater negative affective state, and subsequently avoidance of the aversive stimulus.

As well as engaging attention, it has also been proposed that aversive stimuli impair the disengagement of attention. The disengagement component of attention serves to block out any distracting information; attention to other competing stimuli is inhibited in order to enhance processing of a stimulus (M. I. Posner, Inhoff, Friedrich, & Cohen, 1987). In the context of attention to aversive stimuli this may be critical in order to sufficiently process a threat in order to initiate an appropriate defensive action (Lang et al., 1997). As previously discussed, cueing paradigms have been essential in separating the engagement and disengagement components of attention. Slower responding for a target on invalid trials containing threatening cues relative to trials using neutral cues indicates a greater impairment in disengagement for the threat cue. Using this procedure Koster et al. (2004, 2005) reported that a stimulus previously associated with an aversive white noise outcome and presented for 200ms generated slower reaction times relative to trials using a neutral cue. However, Yiend & Mathews (2001), who used a similar paradigm, found that high-anxious individuals, but not low-anxious individuals exhibited an impaired disengagement on invalid trials with threat cues presented for 500ms. As Koster et al. (2005) did not separate high and low anxious individuals it is impossible to judge whether impaired disengagement of attention is a stable feature of aversive stimuli, or varies as part of individual differences in aversive motivation. Other differences between the studies in terms of type of threat stimuli used, and cue duration also make any conclusions difficult.

Attentional biases in high trait anxiety individuals

In addition to the concept that threatening stimuli may capture attention, and impair disengagement of attention, there are contrasting theories concerning how attention may be allocated for such stimuli in clinically anxious individuals. According to some theories, attentional biases for threat stimuli are enhanced in these individuals, while other models argue that avoidance effects are stronger. Evidence is mixed, but it does appear that those experiencing higher trait levels of anxiety do exhibit both enhanced engagement and greater impairment in disengaging from threatening stimuli. Fox, Russo, Bowles, & Dutton (2001a) reported that disengagement for threat stimuli in a cueing paradigm was more enhanced in a high trait anxiety (HTA) group relative to a low trait anxiety (LTA) group, while there was no difference between groups in the engagement bias for threat cues. However, this study used schematic faces as the threatening stimuli, which may not have been threatening enough to induce an enhanced capture of attention. In a similar paradigm, but using threatening pictures from the International Affective Picture System as the cues, Koster, Crombez, Verschuere, Van Damme, & Wiersema (2006) reported that only the HTA group elicited attentional biases at 100ms for threatening stimuli relative to neutral stimuli, indicating that automatic attentional engagement was faster in this group.

The aforementioned studies appear to support the theory that threatening stimuli are attended to more in high trait anxious individuals. However, stimulus durations in these studies were relatively short, and may not have detected avoidance effects. Certainly, in accordance with the “vigilance-avoidance” hypothesis (Mogg, Bradley, Miles, & Dixon, 2004) there is also evidence that for prolonged stimulus presentations (>100ms) threatening stimuli are avoided in clinical and high trait anxious individuals. Indeed, Koster et al. (2006) reported that HTA individuals exhibited avoidance of threatening cues relative to neutral cues for a 500ms stimulus duration. However, in a similar paradigm Mogg, Bradley, et al. (2004) reported that at 500ms HTA individuals had greater attention for threatening images than LTA individuals, and neither group showed attentional avoidance at 1500ms. It is difficult to account for such a discrepancy between these two studies as both used highly arousing and threatening stimuli. However, Mogg, Bradley et al. (2004) also reported that individuals high in fear relating specifically to blood-injury did exhibit attentional avoidance for images depicting mutilated bodies. Thus, avoidance may only occur when the stimulus elicits a specific fear response, rather than general anxiety. Certainly, although traditional theories of anxiety do not differentiate between fear and anxiety states (Beck & Rush, 1985; Mogg & Bradley, 1998), there is evidence that they may be mediated by separate neural mechanisms and reflect two different motivational states (Lang et al., 2000; McNaughton & Gray, 2000). “Fear” is conceptualised as a response to explicit threat cues and characterised by defensive avoidance of the cue that facilitates escape from dangerous situations (Lang et al., 2000). “Anxiety” is conceptualised as a more general distress state in response to non-specifc threat cues, which occurs when vigilance for threat cues conflicts with avoidance of threat (McNaughton & Gray, 2000). Thus, avoidance should be incurred for specific fearful stimuli (as in phobias) as it activates a “fear” state, while generalized anxiety, should lead to enhanced vigilance and monitoring as reflected in findings that greater trait anxiety induces faster detection of, and more impaired disengagement of attention for general threat stimuli. In the context of a conditioning paradigm, therefore, it would be expected that attention for the conditioned stimulus, as it is a discrete cue, should be related to activation of a fear system rather than an anxiety system. However, additional initiation of an anxiety state cannot be ruled out.

Summary

Non-drug reward stimuli appear to attract attention in a similar manner to drug stimuli. That is, they both capture attention and attention is maintained voluntarily, indicating that a non-drug reward may be used in place of a drug reward in the current investigation. Capture of attention for aversive stimuli is also reported in the literature. However, according to some literature, while attention may be initially engaged by a threat, it is subsequently avoided, while other theories suggest that threat stimuli impair the disengagement of attention. Consequently, separate measures of the initial capture and subsequent maintenance of attention should be obtained in the current investigation in order to separate these theories. In addition, there may be differences in attention for threats in high and low trait anxious individuals. While this difference is not addressed in the current study, it may have implications in the application of findings to different clinical populations.

1.5 Attention for stimuli predictive of an outcome

Models of attention and learning

As well as emotional theories of attention, other theories propose that learning mechanisms may also mediate attention. Learning how to predict the occurrence of a significant event clearly has important implications in the survival of an organism, and as will presently be discussed, there may be a role for attention in such learning. Models of learning, such as the Rescorla–Wagner (1972) model, formalize how the associative strength develops between a signal (a conditioned stimulus) and a significant event (unconditioned stimulus). According to this model learning occurs not simply because two events co-occur but because that co-occurrence is unanticipated on the basis of current associative strength. Thus, learning is driven to the extent that there is some discrepancy between whether the outcome is expected, and whether or not it occurs (the error term). This model also states that the change in strength of the association between a cue and an outcome is reliant on several other fixed factors including the salience of the cue and the salience of the outcome eg. the arousing properties of a stimulus, as well as an error-term reflecting the discrepancy between the expectancy and occurrence of an outcome. Theories of attention contribute to this learning model by elucidating the mechanisms through which associative learning develops. Animal data on observation behaviour during learning does appear to support the concept that learning about a stimulus depends upon attending to that stimulus. For example, in pigeons the control of instrumental responding by a stimulus predictive of a food outcome is positively correlated with the amount of time spent observing that predictive stimulus relative to a nonpredictive stimulus (Dinsmoor, Mueller, Martin, & Bowe, 1982). Similar data have been found in rats and humans, and these findings will be discussed in greater detail in due course. Such findings have led to the addition of an attentional component to models of associative learning.

One major attentional theory of learning postulates that attention is driven by the error-term produced by the discrepancy between the expectancy and occurrence of the outcome (Pearce and Hall, 1980). According to this theory, associative learning between two stimuli is facilitated by attentional mechanisms that are directed towards stimuli according to the size of this error-term. Error-driven learning is related to the concept that selective attention to stimuli involves a limited capacity processor. The relationship between cognitive processing and attention has been demonstrated through studies reporting that increasing the cognitive load during a word target detection task decreased the ability to attend to the word stimuli (Dark, Johnston, Myles-Worsley, & Farah, 1985). There is also evidence that neural representations of stimuli may compete with other representations at the sensory level in order for selective attention to occur (Desimone & Duncan, 1995). This concept relates to prediction-error learning, as stimuli that are fully predictive will no longer be captured by attention, and this should subsequently decrease the cognitive load.

In terms of the progression of attention during a conditioning procedure, error-driven models of learning state that attention will be allocated to a conditioned stimulus (Cs) during learning, but that once the associative strength between the two stimuli has reached asymptote, attention will decrease to the CS. Furthermore, according to Pearce and Hall (1980), attention to a CS may occur in an automatic or controlled manner: automatic processing of a CS is sufficient to support an existing association between the CS and a response (conditioned or unconditioned), while controlled processing is required for a CS to support new learning (i.e. to become associated with another unconditioned stimulus or a response). Controlled processing of a CS remains low as long as the CS consistently and accurately predicts expected consequences, but increases when it does not accurately predict important stimulus events. Thus, attention is biased towards a stimulus to the extent that it is an uncertain predictor of an outcome.

An alternative model of learning and attention argues that learning is driven by the predictive salience of a stimulus rather than the prediction error (Mackintosh, 1975). That is, learning is driven by the number of times a stimulus has been paired with a significant outcome. As with the error-driven model, an attentional mechanism may be mediating this learning process. Thus, the Mackintosh model is often interpreted as an attentional model whereby learning is facilitated through the increasing salience of the predictive stimulus attracting more attention. Other versions of this model have proposed that it is the predictive *validity* of the stimuli rather than the number of pairings with the outcome that attracts attention (Kruschke, 2003). Regardless of the exact mechanism, both of these models predict that attention should be allocated to a CS even after the outcome is fully predicted, whilst prediction-error models of learning state that attention should diminish to the CS once the outcome is fully predicted. The predictive salience theory of attention has elicited some support due to its ability to account for conditioning phenomenon such as blocking. In the blocking procedure, a person initially learns about an outcome from a single cue; when the cue is subsequently accompanied by a second cue and is presented with the same outcome, there is not a strong associative learning between the second cue and the outcome - learning is essentially blocked for this second cue (Kamin, 1969). According to predictive salience theories, learning is blocked for the new cue because the previously salient cue attracts attention and the new cue, possessing less predictive salience, is ignored (G. Hall, Mackintosh, Goodall, & Dalmartello, 1977). However, blocking can also be explained by prediction-error theories in the following way: while the new stimulus may be attended to on the first trial in the second phase, it is subsequently not attended to on the following trials because the outcome is already predicted by the previous stimulus, and therefore learning for this new stimulus is inhibited due to its failure in producing a prediction error (Tobler, O'Doherty J, Dolan, & Schultz, 2006). There is one effect, however, that predictive salience models uniquely account for, and this is intra-dimensional transfer effects. One study reported that when participants were trained to discriminate stimuli according to intradimensional properties this facilitated responding for a subsequent phase where a response was made according to discriminative intradminensional properties (Bonardi, Graham, Hall, & Mitchell, 2005). In contrast, a group trained to discriminate stimuli according to extradimensional properties did not perform as well in this subsequent phase. The Mackintosh (1975) theory argues that the facilitation of performance in the intradimensional group is due to the prior training to attend to the intradimensional qualities of the stimuli. Pearce and Hall (1980) fail to explain this transfer effect as they predict that prior training along one dimension should not bias attention to that same dimension in a subsequent phase.

While Mackintosh (1975) and Kruschke (2003) models are unique in their ability to account for intra-dimensional transfer effects, and are valid models of learning-driven attention, they will not be the focus of the current investigation. The predictions of these models are (in general) less in opposition to emotional theories of attention than error-driven models. Predictive salience models and affective-motivational models of attention predict that attention to a CS will continue even after learning has occurred, while error-driven models of attention predict that attention will decrease to a CS after learning has occurred. Error-driven theories have more relevance to models of addiction and anxiety as they insinuate that attentional biases to conditioned cues cannot play a role in the maintenance of such disorders. Thus, while the author acknowledges the existence of the predictive salience model, the prediction-error model of learning will be the focus of the current investigation.

Attention for stimuli predictive of an affective outcome

Prediction error models appear to make contradictory claims to emotional models concerning the allocation of attention to cues predictive of an affective outcome. While the extent to which error-driven mechanisms mediate attention during learning for affective events has been investigated extensively, there appears to be multiple discrepancies in the data, which need to be addressed. In animals, there is some support for the prediction-error hypothesis as in a study using rats the orienting response for a stimulus predictive of a food outcome diminished after learning had occurred (Kaye & Pearce, 1984). In addition, this study incorporated a stimulus that was a partial predictor for a food outcome, and the orienting response was maintained for this stimulus throughout conditioning. As a partial predictor would have the highest uncertainty (largest error-term) this supports a model of attention as driven by prediction error. Furthermore, there is substantial neural evidence for a prediction error substrate in reward learning. In a series of experiments, Schultz (1998) demonstrated that midbrain dopamine neurons responded in accordance with a prediction error signal. Specifically, Dopamine neurons in this region were activated by rewarding events that were better than predicted, remained uninfluenced by events that were as good as predicted, and were depressed by events that were worse than predicted. Activity recorded from monkey Dopamine neurons in the ventral tegmental area and substantia nigra areas in response to rewarding events revealed that activity was high during the early stages of learning when more errors were made and rewards were less predictable, but decreased as learning progressed and rewards were more predictable (Hollerman & Schultz, 1998).

While there appears to be support for error-driven mechanisms of attention for rewarding outcomes in the neuropsychological animal literature, there has been less evidence from studies on attention for rewarding events in humans – largely due to the fact that this has been studied less extensively in humans compared to animals. In fact, one study using tobacco as the unconditioned reward in an instrumental conditioning paradigm reported that attention (as measured by an eye-tracker) was allocated more to a stimulus predictive that a response would be reinforced by cigarette reward (CS+) compared to a stimulus that signalled a response would not result in a cigarette reward (CS-) (L. Hogarth, Dickinson, Hutton, Elbers et al., 2006). Although such findings initially appear to contradict the reports from the animal literature, nicotine may be a more salient reinforcer in humans than food is in rats, and this increased affective saliency for the nicotine outcome may account for attention being determined by the affective value in this specific example. It could also be argued that the instrumental response in the smoking study may have been in some way responsible for this discrepancy with the animal study. However, Hogarth, Dickinson, & Duka (2009) reported that in an instrumental conditioning paradigm and under certain experimental conditions, attention was maintained for a CS+ predictive of a cigarette outcome, even after learning had occurred. Whilst this is strong evidence against the prediction-error theory of attention, both the Hogarth et al. (2006) and the Hogarth et al. (2009) failed to include a partial predictor, and therefore, a role for uncertainty in attention for rewards cannot be completely dismissed.

Unlike with reward outcomes, Dopamine neurons don't appear to respond to aversive outcomes (Mirenowicz & Schultz, 1996), indicating that Dopamine may only be responsible for learning about rewarding outcomes. However, there is some evidence that serotonin is involved in learning about aversive outcomes (Dayan & Huys, 2008). In support of the role of prediction errors in aversive learning, activity was reduced in the amygdala in response to a CS, once it fully predicted an aversive outcome (Dunsmoor, Bandettini, & Knight, 2008). Additional behavioural evidence also lends support to the role of prediction error in aversive learning. Hall & Pearce (1979) conducted a Pavlovian conditioning study in rats using shock as the unconditioned stimulus. The design of the experiment is depicted in Table 1.1. One group of animals experienced the tone with no outcome, another the tone paired with a mild electric shock, and a third group experienced a light paired with a mild electric shock. In a second phase all groups experienced the tone with a stronger electric shock and conditioned suppression was measured.

Table 1.1 Design of Hall and Pearce (1979)

Group	Phase 1	Phase 2
Tone-Alone	Tone + nothing	Tone + strong shock
Tone-Shock	Tone + mild shock	Tone + strong shock
Light-Shock	Light + mild shock	Tone + strong shock

The findings demonstrated that the rats in the light-shock group demonstrated more fear to the tone in Phase 2 than the tone-shock group, which in turn demonstrated more fear than the tone-alone group. Only prediction error theories of learning can explain why a greater conditioned fear response was elicited for the light-shock group compared to the tone-shock group. This is because the tone-shock group have already learnt the meaning of the tone from their experience of it in Phase 1. Consequently, the salience of the tone is lower and subsequent learning of the tone with a strong shock is impaired compared with the light-shock group. Whilst this is particularly strong evidence in favour of an error-driven theory of learning, there seems to be no animal studies reporting that after learning of an aversive outcome has occurred *attention* is reduced to the conditioned stimulus. Nor has there been animal studies comparing attention to a full and a partial predictor of an aversive event, in contrast to the Kaye and Pearce (1984) study where a food reward was the unconditioned stimulus. Thus, while learning may well be driven by prediction error, the extent to which this is mediated by attention is not so well substantiated according to the behavioural animal literature. In contrast, there is some evidence for error-driven attention in aversive learning from the human behavioural literature. Attention, as measured via eye-movements, decreased for a stimulus predictive of an aversive noise outcome once learning of the stimulus contingencies was complete (L. Hogarth, Dickinson, Austin, Brown, & Duka, 2008). In addition, attention was maintained for a partial predictor (a stimulus that was reinforced on 50% of trials). As a partial predictor would have the highest uncertainty this supports the theory that attention is determined by prediction error. However, the unconditioned stimulus used in this study was 97db, which may not be considered a particularly aversive stimulus. Indeed, the conditioned stimulus yielded low subjective ratings of unpleasantness – a mean of 4.2 on a 1 to 10 Likert scale.

Summary

It is clear that while there is a great deal of neural evidence that learning of affective outcomes may be mediate by predictive uncertainty, for rewarding outcomes there are contradictory findings between the animal and the human behavioural literature, while there is a definite lack of attentional data during conditioning for aversive outcomes (particularly in the animal literature). In the absence of any substantial data in humans in support of error-driven attention, I suggest that attention is most likely determined by the affective value of the conditioned stimulus rather than its predictive uncertainty.

1.6 Materials and General Methods

General terminology

In section 1.3 various concepts regarding the properties of aversive and appetitive stimuli were discussed. It was established that these stimuli have both hedonic affective (associated with “like” and “dislike”) and motivational (associated with approach, avoidance and autonomic arousal) properties. The purpose of the current investigation was not to separate which of these components may be responsible for guiding attention, although at times the possibility of such a separation will be discussed. To avoid confusion, the term “incentive” will be used throughout investigations when referring to the combined affective and motivational attributes of aversive and appetitive stimuli. Although there may be different uses of these terms in the literature, the term “incentive” seemed to be the most appropriate in combining affective and motivational value.

Conditioning procedure

In order to induce associative learning, a discriminative conditioning paradigm will be employed. Discriminative conditioning procedures compare responses in the presence of a predictive stimulus (CS+) with responses for a stimulus that is paired with the absence of the unconditioned stimulus (CS-). Although comparison of attentional responses between the CS+ and the CS- throughout conditioning should be sufficient to determine whether attention is mediated by prediction error or incentive value, the inclusion of a partial predictor should provide further clarification of these mechanisms of attention in learning. According to the Pearce and Hall (1980) model of learning, attention for a CS+ should be reduced to the level of the CS- after learning has occurred, while attention should be sustained for a partial predictor due to its high level of predictive uncertainty. In contrast, incentice theories predict that as the CS+ becomes progressively associated with the affective and motivational properties of the outcome, attention will increase for this stimulus relative to a CS-. Attention for a partial predictor should also increase over conditioning, but ought to be less than for the CS+ as the result of a weaker incentive association. Thus, the inclusion of a partial predictor will provide further assistance in separating the contrasting models of attention. Accordingly, the discriminative conditioning procedure in the present design will involve three different outcome contingencies – a CS+, CS+/-, and a CS-. The CS+ will confer a 100% probability, the CS+/- a 50% probability, and the CS- a 0% probability that the outcome will occur on that trial. Prior studies have found that 144 trials with these three stimulus types was sufficient to induce conditioning according to subjective ratings (L. Hogarth, Dickinson, Austin et al., 2008), and consequently the number of trials used in the current investigation will be based on this approximation. During conditioning, predictive stimuli will be presented as part of a stimulus pair with another non-predictive redundant stimulus (stimulus X). This is in order to measure selective attention, as will presently be discussed in the section concerning measures of attention.

The conditioned stimuli used will be visual abstract stimuli, which have previously been successfully conditioned to both appetitive (L. Hogarth, Dickinson, Janowski, Nikitina, & Duka, 2008; L. Hogarth et al., 2007) and aversive outcomes (L. Hogarth, Dickinson, Austin et al., 2008). These stimuli will be presented using relatively neutral, non-arousing colours from a grey-scale rather than colours with arousing properties. Certain colours have been known to increase or decrease positive mood (Hamid & Newport, 1989) and to affect performance on cognitive tasks (Kwallek & Lewis, 1990). These findings indicate that bright colours have arousing properties that via interference with mood and cognition may confound attention and learning in the current study. Abstract stimuli were chosen as participants were unlikely to have had prior experience with them. Prior experience with a conditioned stimulus may influence conditioning for a new unconditioned stimulus due to phenomena known as “blocking” and “latent inhibition”. If a stimulus is previously paired with an outcome then it will “block” learning for another stimulus when subsequently presented together and paired with the outcome (Bakal, Johnson, & Rescorla, 1974). This has relevance for the current study as stimuli will be presented in pairs; thus, conditioning for the predictive stimulus may be retarded if the redundant control stimulus (X) has been previously associated with the outcome prior to the conditioning procedure. Latent inhibition occurs when a stimulus has been experienced without any consequences and during subsequent pairing with an outcome associative learning is retarded (R. A. Rescorla, 1971). This relates to the current paradigm as prior experience of the predictive stimuli without consequence could lead to inhibited learning for the new outcome.

Measures of learning

Measures of learning are required to ensure that participants have learnt the contingency relationships. Subjective ratings of expectancy for an outcome have been used to assess learning of the CS-US contingencies in a variety of designs and with many different reinforcers (Bechara et al., 1995; Coppens, Spruyt, Vandenbulcke, Van Paesschen, & Vansteenwegen, 2009; Dawson & Biferno, 1973; L. Hogarth, Dickinson, & Duka, 2005). Some of these measures of expectancy also incorporate a Likert-scale of responding (L. Hogarth, Dickinson, Austin et al., 2008; L. Hogarth et al., 2005; L. Hogarth, Dickinson, Hutton, Bamborough, & Duka, 2006). Expectancy ratings appear to be a valid measure of conditioning as they tend to occur concurrently with measures of conditioned responding such as increased skin conductance response (Dawson & Biferno, 1973) and changes in heart rate (Neumann & Waters, 2006). Clearly, subjective expectancy ratings do not necessarily represent implicit learning processes, which may be indexed by conditioned responses such as skin conductance activity. However, discriminatory skin conductance responses in the absence of explicit learning only occurs in exceptional circumstances, such as when fear-relevant stimuli such as spiders and snakes are the conditioned stimuli (Ohman & Soares, 1998). Skin conductance responses are also not an ideal measure of learning as according to subjective expectancy ratings, some individuals may acquire knowledge of the CS-US contingencies in the absence of discriminatory SCRs (Dawson & Biferno, 1973). Consequently, subjective expectancy ratings were considered the most appropriate measure of learning for the current investigation.

Measures of incentive salience

The emotional response elicited by the conditioned stimuli will also be a dependent measure in the current design in order to ensure that the conditioned stimuli acquire appropriate incentive attributes, and to verify the existence of a relationship between attention and incentive value. Previous conditioning studies have obtained levels of emotional conditioning via Likert-scale subjective ratings of pleasantness or anxiety (L. Hogarth, Dickinson, Austin et al., 2008; L. Hogarth et al., 2005). Self-reported ratings of emotional conditioning also appear to possess good validity as a measure of a conditioned emotional response as they also tend to co-occur with physiological measures of affective conditioned responding. Neumann & Waters (2006) reported that pleasantness ratings for a conditioned stimulus paired with an unpleasant noise decreased over trials in parallel with increasing startle blink amplitude. However, use of subjective ratings to obtain a measure of the emotional conditioned response is clearly contingent on conscious awareness of the CS-US contingency. Indeed, Hogarth, Dickinson, Hutton, Bambourough et al. (2006) reported that only those individuals who had conscious knowledge of the stimulus contingencies also reported discriminatory emotional responses for the CS+ and CS- as measured by subjective ratings. Some theories of learning state that emotional learning occurs in neural circuits distinct from cognitive conscious learning (Damasio, 1996; J. E. Ledoux, 1993), signifying that subjective ratings may fail to encompass some aspects of emotional conditioning. However, as discussed in a previous section, conditioned responses (including emotional responses) tend to be reliant on cognitive awareness of the CS-US contingencies (Dawson & Furedy, 1976). Hence, subjective ratings should be a legitimate measure of the emotional conditioned response.

The motivation to obtain a reward or avoid an outcome may also be an index of the incentive value of the stimulus. To some extent, motivational properties should parallel the affective value of the stimuli as increased motivation for an outcome is associated with increases in affective value. For example, Berridge (1991) reported that in rats, increasing the motivation to obtain a food reward via manipulation of hunger subsequently increased positive hedonic affective responses for that food. However, Bradley, Field, Healy, & Mogg (2008) reported that attentional biases in smokers for drug cues were mediated by the motivational properties of the cues rather than their affective properties, indicating that motivational processes may also be dissociated from the hedonic-affective value of incentive stimuli. Thus, measures of motivation may be required in the current study as both an additional indication of incentive value of the outcome, and in order to eliminate it as a possible confound in attentional data. Motivation is most commonly measured using behavioural responses to obtain a reward or avoid a punishment. These measures of motivation normally involve calculating either the rate or number or responses made whilst completing a schedule of reinforcement. The variable interval schedule is one such behavioural measure of motivation that has been applied successfully in both humans and animals. The basic premise of this schedule is that reinforcement is delivered for the first response after a random average length of time passes since the last reinforcement (Hilgard & Bower, 1966). For example, on a VI 10 schedule reinforcement is provided for the first response after an average of 10 seconds since the last reinforcement. As the time point in which an instrumental response is reinforced varies, the organism should accumulate a steady response rate that reflects their level of motivation (Hilgard & Bower, 1966). In animals, this method has been used extensively to measure nondrug and drug rewards. Studies using rats have found that when sucrose concentration was increased, response rate on a lever to obtain the sucrose likewise increased (Bradshaw, Ruddle, & Szabadi, 1981; Bradshaw, Szabadi, & Bevan, 1978). The same procedure has also been employed in humans. Enhanced responses rates were found for humans in the presence of a CS+ on a VI schedule in order to obtain a monetary reward or to avoid a monetary loss (Ruddle, Bradshaw, Szabadi, & Foster, 1982). Furthermore, Glautier, Bankart, Rigney, & Willner (1998) found that the variable interval schedule generated greater response rates for a 1.5 pence reinforcer over a 0.5 and 0.1 reinforcer, indicating that even where there is very little difference in reinforcer value, it is a highly sensitive measure of motivation. Fixed schedules of responding (eg. fixed interval and fixed ratio) tend to yield response patterns that change over time i.e. scallops and/or break-runs turn into low-rate patterns

(Wanchisen, Tatham, & Mooney, 1989). The variable ratio procedure (where reinforcement is contingents on a variable number of responses), although also yielding smooth response patterns, tends to have a very steep response gradient (Hilgard & Bower, 1966); as such, a variable ratio schedule may be less sensitive to differences than a variable interval schedule when comparing different levels of value as it may generate ceiling effects. Another popular measure of motivation used in humans is the progressive ratio schedule. This is an extended version of the fixed-ratio schedule of reinforcement, but in this instance subjects must meet increasing ratio response requirements in order to receive a reinforcer (Hodos, 1961). For example, on the first trial reinforcement is delivered after 10 responses, but on each subsequent trial the number of responses required increases by a set increment eg. by 2. In this example the number of responses required to obtain reinforcement on each subsequent trial would be 10, 20, 30, 40 etc. Reinforcing efficacy of a stimulus using this procedure is indexed by the “breaking point”. Breaking points may be defined as the number of responses made, the number of reinforcers obtained, or the highest ratio completed (Richardson & Roberts, 1996). While progressive ratio schedules do tend to have high validity in predicting the reinforcing efficacy of a number of reinforcing outcomes – particularly drug rewards (Stafford, LeSage, & Glowa, 1998), criticisms of this type of schedule have included the fact that, as with the variable ratio schedule, it is liable to yield ceiling effects (Richardson & Roberts, 1996). In addition, studies in humans using progressive ratio schedules tend to necessitate lengthy reinforcement schedules – Hughes, Pleasants, & Pickens (1985) reported that some participants took up to 137 minutes to complete a progressive ratio schedule of reinforcement. Thus, the variable interval schedule may be a more practical, as well as a more sensitive, measure of motivation for the current investigation.

Another measure associated with the value of incentive stimuli is autonomic arousal. This measure is thought to reflect the motivational aspects of incentive stimuli rather than the hedonic affective properties. Lang et al. (1997) proposed that the arousal response elicited in the presence of appetitive or aversive stimuli acts as the indicator of the presence of a motivationally-relevant event. One measure of autonomic arousal is the skin conductance response, which is reportedly unrelated to hedonic affective properties of stimuli: Levels of self-reported arousal, but not valence, are associated with increased skin conductance responses for both auditory (Gomez & Danuser, 2004) and visual (Lang et al., 1993) stimuli. Whilst skin conductance responses may be used to provide additional clarification concerning the exact mechanisms of incentive attention, it was not initially introduced into the conditioning paradigm for practical purposes. On-line measures of arousal were not used in the original discriminative learning procedure (L. Hogarth, Dickinson, Austin et al., 2008), and therefore it did not seem appropriate to include such measures prior to establishing the efficacy of the paradigm. Furthermore, there is some evidence that subjective ratings of affect also tend to parallel the arousing properties of the stimuli, although this relationship is stronger for negatively-valenced stimuli (M. M. Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang et al., 1993). Thus, subjective ratings of affect may encompass some arousing/motivational aspects of incentive stimuli as well as the hedonic affective value.

Contingency awareness

Only those who are consciously aware of the stimulus contingencies by the end of the conditioning session will be included in the analysis. This is because only those participants that acquire an explicit awareness of the contingencies will exhibit selective attentional and emotional responses (see Hogarth & Duka (2006) for a review). Previous studies have found that those who don't acquire explicit knowledge of the outcome contingencies, also fail to show selective attentional, emotional, and behavioural conditioned responses for conditioned stimuli. Hogarth, Dickinson, Hutton, Bamborough et al. (2006) reported that only those subjects who exhibited significantly higher expectancies of an aversive noise occurring in the presence of a CS+ also displayed selective attention for the CS+ over the CS-, and discriminatory anxiety ratings and avoidance responses. Similar findings were reported when a rewarding cigarette outcome was the reinforcer (L. Hogarth, Dickinson, Hutton, Elbers et al., 2006). For the present investigation, the criteria for contingency-awareness used in a number of prior conditioning studies (on which the current design is based) was employed. Accordingly, in the final block of conditioning (final 36 trials) only those participants whose mean expectancy for the outcome on a CS+ trial was greater than on a CS- trial were considered contingency-aware and included in the final analysis. This criteria was used in the aforementioned Hogarth, Dickinson, Hutton, Elbers et al. (2006) and Hogarth, Dikcinson, Hutton, Bamborough et al. (2006) studies, where only those who were aware according to this criteria exhibited selective attention and discriminatory conditioned emotional responses. In order to promote contingency-awareness, expectancy ratings were presented after every trial. Continuous prompting of expectancies on a trial-by-trial basis has previously been found to increase awareness as measured on a post-experimental contingency-awareness questionnaire (Dawson & Biferno, 1973).

Measures of attention

In order to measure selective attention, specific methodological procedures must be applied. Selective attention to a stimulus may be measured when two stimuli are presented concurrently; the amount of attention allocated for one stimulus over another is a measure of the selective attention for that stimulus (M. I. Posner, 1980). Hence, it will be necessary to present affective stimuli as part of a stimulus pair. Eye-tracking is a useful tool to measure selective attentional processes because unlike with dot-probe tasks it is not confounded by the length of stimulus duration. Dot-probe tasks may not provide such accurate measures of attention because they measure attention during a specific time-point set by the experimenter, whilst attention may be directed away and towards a stimulus several times during stimulus presentation. Eye-tracking removes this confound as it tracks attention during the entire stimulus presentation. There has been some hesitation over the use of eye-tracking as a measure of attention as it is possible for covert attentional processes to be separated from overt saccadic eye movements (M. I. Posner, 1980). However, studies have found that when subjects are free to move their eyes covert and overt attention doesn't tend to dissociate (Gilchrist, Brown, Findlay, & Clarke, 1998). Overt eye movements to a target are guided by information viewed parafoveally (Kean & Lambert, 2003), and if a saccade is observed this may be taken as evidence that the observer attended to the target prior to initiating the saccade (Deubel & Schneider, 1996). Indeed, overt eye movements appear to be a valid measure of attention as they concur with other measures of attention. Isaacowitz, Wadlinger, Goren, & Wilson (2006) reported that eye movements as measured through eye-tracking matched the direction of attention as measured through latencies to respond on the dot-probe task, although attention as measured through eye-tracking provided more robust results.

Eye-tracking is also a useful tool to separate the different components of selective attention such as the early initial orientation of attention, and later sustained aspects of attention. The inclusion of different measures for early automatic, and later controlled processing of attention was used as a tool to separate different theories of attention for threats and rewards. In the context of eye-tracking, initial orientation of attention can be measured by latency to first fixation (Bannerman et al., 2009; Calvo, Nummenmaa, & Hyona, 2007) or the likelihood that a stimulus is fixated to first relative to a competing stimulus (Alpers, 2008; Calvo & Lang, 2004; Nummenmaa, Hyona, & Calvo, 2006b). However, the latency measure only appears to be sensitive to emotionality at short stimulus durations, but disappears at long stimulus durations (Bannerman et al., 2009), while probability of first fixation is sensitive to emotionality at both short (Calvo et al., 2007) and long stimulus durations (Nummenmaa, Hyona, & Calvo, 2006a). Thus, probability of first fixation appears to be a more robust measure of the initial capture of attention, and was consequently the preferred measure of attentional capture in the current study. The subsequent maintenance of attention may be measured through the total dwell time spent on a stimulus in comparison to a competing stimulus. Total dwell time has been used as a measure of learning in several studies employing a variety of positive and negative outcomes in humans (L. Hogarth, Dickinson, Austin et al., 2008; L. Hogarth, Dickinson, Hutton, Elbers et al., 2006). Another method of measuring cognitive conscious attention is by allowing the participant to control how long they view the stimulus through pressing and then releasing a button (L. Hogarth et al., 2009). However, this measure clearly does not separate early and late components of attention.

Total duration of fixations and probability of first fixation have also been shown to be related to automatic and controlled processes respectively. In their investigation Nummenmaa et al. (2006) included a condition where participants were instructed to attend to either the emotional, or the neutral stimuli. They found that attention as measured by total duration of all fixations appeared to be entirely under cognitive control as durations were longer for whichever stimulus they were told to look at, regardless of its emotional significance. In contrast, probability to first fixation was always greater for emotional stimuli regardless of whether they were instructed to attend it, signifying that this measure of attention may reflect automatic processes to some extent (in accordance with the definition of automaticity, see section 1.4). That said, instructions to attend to the neutral stimuli did reduce the probability of attending first to the emotional stimuli, indicating that there is some element of cognitive control even at this early stage of attention. However, it is clear from these findings that while probability of first fixation may encompass some aspects of the automatic components, as well as controlled aspects, of attention, total dwell time is a pure reflection of the conscious voluntary control of attention.

Questionnaires

Individual differences in motivation and mood state, and the presence of emotional pathological disorders may all influence conditioning rates and the allocation of attention. According to some models of motivated learning and behaviour, motivation to avoid punishments and motivation to obtain rewards are governed by separate systems. The physiological mechanism controlling avoidance motivation are often referred to as the behavioural inhibition system (BIS) (Gray, 1988), and the system controlling approach motivation is known as the behavioural activation system (BAS) (Fowles, 1980).

According to Fowles (1980) higher BIS activation is related to increased responsiveness for punishment, while higher BAS activation is related to increased responsiveness to rewards. As it is hypothesised that the BIS and BAS systems are governed by separate and distinct mechanisms, it follows that there may be individual differences in these systems rendering some individuals more sensitive to rewards, and others more sensitive to punishments. Carver & White (1994) developed a subjective scale which was able to measure these two types of motivation. It measures one category for behavioural inhibition, and three subsets of behavioural activation: reward responsiveness, reward drive, and fun-seeking. According to their model "*The Drive scale is made of items pertaining to the persistent pursuit of desired goals. The fun-seeking scale has items reflecting both a desire for new rewards and a willingness to approach a potentially rewarding event on the spur of the moment. The reward responsiveness scale has items that focus on positive responses to the occurrence or anticipation of reward*" (pp. 322). The scale itself is a 24-item response questionnaire consisting of 3 subscales of behavioural activation, and one 7 item subscale of behavioural inhibition. BIS consists of seven items measuring apprehensive anticipation (e.g. "I worry about making mistakes" or "I have few fears compared to my friends"). BAS was composed of three subscales: BAS Drive (BASD; four items; e.g. "When I want something, I usually go all-out to get it"); BAS Fun-Seeking (BASF; four items; e.g. "I often act on the spur of the moment"); BAS Reward Responsiveness (BASR; five items; e.g. "When I get something I want, I feel excited and energized'). All items are Likert scaled (4 points) with anchors of "strongly agree" and "strongly disagree". Scores on the BIS/BAS scale correlate with other measures of avoidance and approach motivation, indicating it is a valid measure of motivation. Amodio, Master, Yee & Taylor (2008) found that those scoring high on the BAS subscales also had greater frontal cortical asymmetry – an area thought to be associated with approach orientation. Behavioural evidence also supports the validity of the scale as investigators found that high BAS scores predicted the development of a response bias for a rewarding version of the go/no go paradigm (Smillie & Jackson, 2006). Likewise, there is also evidence that the BIS is a valid measure of avoidance motivational sensitivity. Higher BIS scores were related to greater attentional responses for stimuli associated with aversive events, and increased behavioural avoidance responses for novel stimuli (A. P. Field, 2006).

Anxious and depressive mood states may also enhance attention for emotional information. Bradley, Mogg, & Lee (1997) reported that naturally occurring and induced dysphoric mood enhanced attention for negative words according to performance on a dot probe task. It is also well documented that a greater anxiety state is related to attentional biases for threatening information (Broomfield & Turpin, 2005; Mathews & MacLeod, 1985; Mogg & Bradley, 1998). Induced anxiety mood has also been shown to enhance selective attention for threatening information in both the Stroop and the dot-probe task relative to a group that did not have the mood induction (L. S. Fox & Knight, 2005). Those who exhibit anxiety and depression as pathological disorders may also demonstrate differences in attention for emotional stimuli. Bradley et al. (1999) described how a sample presenting with generalized anxiety disorder exhibited enhanced vigilance for threatening faces over happy and neutral faces compared to controls in a dot-probe task. Mogg, Philippot, & Bradley (2004) reported a similar finding for participant’s diagnosed with social anxiety disorder, indicating enhanced vigiliance for threatening stimuli. Clinical depression also yields attentional biases for negative information. Studies using faces as emotional stimuli have found that those participants presenting with depression have an attentional bias for sad faces but not for angry or happy faces (Gotlib, Krasnoperova, Yue, & Joormann, 2004). This bias was unique to the depressed individuals and was not present in controls.

As both negative mood states and pathological emotional disorders appear to bias attention for threatening or negative affective stimuli, two controls were employed in the present design. Those currently being treated for a depressive or anxiety disorder were excluded from the investigation. As current mood state may also influence attention, measures of anxiety and depressive mood prior to conditioning may also help in eliminating mood state as a confound in attentional bias. The Profile of Mood States (POMS; McNair, Lorr, & Doppleman, 1971) is a 65 item adjective questionnaire that is divided into several subscales of mood including anxiety and depression. Various mood states as measured by the POMS have been shown to be correlated with attentional measures (R. A. Cohen et al., 2001), while the scale appears to have good validity as Munafo, Hayward, & Harmer (2006) reported than when a group of depressed medicated patients were tryptophan depleted (a process known to induce depression) these patients reported a small but significant increase in depressive mood as measured by the POMS.

Reinforcers

While drugs are clearly the primary interest in terms of attention to appetitive stimuli, it was considered more appropriate to begin the investigation with a non-drug reinforcer. Attention to, and learning about, cues signalling drug reward may be influenced by many other extraneous variables including dependence level (L. C. Hogarth, Mogg, Bradley, Duka, & Dickinson, 2003) and current motivational state (Cinciripini et al., 2006) of the individual. For example, cigarettes have been commonly used as an appetitive reinforcer in a variety of conditioning paradigms (L. Hogarth et al., 2005; L. Hogarth, Dickinson, Hutton, Elbers et al., 2006; L. C. Hogarth et al., 2003). However, Hogarth et al. (2003), reported that the number of cigarettes smoker per day had a quadratic relationship with stimuli associated with cigarette reward, while Hogarth et al. (2005) found no such relationship in a similar paradigm. Thus, level of dependence has a complex relationship with attentional bias for conditioned rewards. In addition, inability to smoke during conditioning may also endow conditioned stimuli associated with cigarette outcomes with aversive properties, which renders them useless for measuring reward-driven attention. Hutchison, Niaura, & Swift (1999) reported that when smokers were nicotine-deprived, cues that signalled lighting, holding, but not smoking, a cigarettes acquired conditioned aversive properties; they came to elicit attenuated prepulse inhibition of the startle response and increased self-reported negative affect. Money is a useful substitute appetitive reinforcer as it is less likely to be affected by such confounds. While money is traditionally considered a secondary reinforcer as it may be associated with a variety of different primary rewards, its ability to activate an appetitive motivational system is well documented. Mirroring activation of areas associated with primary rewards, the presence of financial rewards has been shown to increase activation in the amygdala, striatum and midbrain regardless of monetary value, while increasing the value of the money elicited parallel increases of activity in the OFC (Elliott, Newman, Longe, & Deakin, 2003). In addition, humans are motivated to work for monetary rewards as demonstrated in a study conducted by Comer, Collins, & Fischman (1997) where heroin addicts made instrumental responses on a dual progressive ratio schedule procedure to gain either money or heroin. When a placebo was the alternative reinforcer, participants selected the responses to obtain the money reinforcer more frequently than the response to obtain the placebo, and break points increased in parallel with increasing monetary value. Monetary incentives will also elicit conditioned appetitive responses. Shiels, Hawk, Richards, & Colder (2007) reported that participants trained to associate a CS+ with a monetary outcome would make a response in order to view that CS+ even though there was no contingency between the observing response and receiving reinforcement. This finding indicates that expectation of a monetary reward may induce an appetitive conditioned response.

A blast of white noise was chosen as the aversive reinforcer. Conditioned stimuli associated with loud noises in a number of procedures have acquired conditioned responses with humans (L. Hogarth, Dickinson, Austin et al., 2008; Knight et al., 2003). Hogarth et al. (2008) also reported that according to subjective responses, stimuli associated with the noise outcome were rated as inducing more anxiety than stimuli that were not associated with the noise outcome. A blast of white noise will also elicit motivated avoidance responding. In animals, blasts of white noise have yielded increased avoidance behaviour using the shuttlebox paradigm (R. A. Hughes & Bardo, 1981), while humans will also perform an avoidance response in the presence of a cue associated with receiving a loud white noise (Loeber & Duka, 2009). Thus, an aversive noise appears to elicit conditioned responses as measured by subjective ratings of anxiety, and it stimulates avoidance responding as evidenced by the findings of instrumental conditioning paradigms.

Ethical issues

The noise stimuli used had to be loud enough to be aversive but it was also important it should not induce any physical damage or undue distress. As there were no subjective reports of undue distress during presentations of 102db of white noise in a prior study

(Loeber & Duka, 2009), this was the maximal level of noise used throughout. Futhermore, participants were paid a maximum of £6.50 for taking part in the noise studies, decreasing the likelihood that an individual would feel any monetary pressures to continue even if they experienced high levels of distress induced by the noise. Individuals who may be more vulnerable to the negative effects of aversive stimuli (such as those being treated for anxiety or depression) were excluded. During procedures using a monetary outcome participants' responses were either not related to whether or not they received the outcome, or involved small amounts of money (not exceeding 50p). Thus, the procedure did not encourage gambling behaviour.

In order to maintain the general well-being of the participants during conditioning they were informed that they could terminate the experiment at any time point, and when the eye-tracker was used participants wore it for a maximum of one hour. Personal information such as medical reports were kept in a locked drawer at all times to maintain confidentialty, while all participant data for reports and publications was coded as a number ensuring that the participants remained anonymous.

Power analysis

A power analysis was conducted in order to ascertain the number of subjects needed to detect a main effect of stimulus. Effect sizes were based on the findings from the Hogarth, Dickinson, Austin, Brown, & Duka (2008) study. Analysis revealed that in order to get a medium effect size of 0.5 the sample should comprise of at least 8 participants. However, because only aware participants were to be used, thus reducing the sample size, 16 participants were still recruited for each condition, as per the original design.

1.7 Aims and hypotheses

This thesis aims to examine the hypothesis that attention to stimuli predictive of a rewarding or punishing event is largely governed by the incentive value of the outcome, regardless of the valence of the outcome. A further aim was to prove that even under circumstances where attention may also be mediated by uncertainty, incentive-driven mechanisms of attention will continue to dominate. I will use a discriminative conditioning procedure to pair arbitrary visual stimuli with rewarding or aversive outcomes and observe subjects' conditioned affective responses and attentional biases to those stimuli. I predict that for both rewarding and aversive outcomes, attention will be governed by the acquired incentive value of the conditioned stimuli rather than by its predictive uncertainty.

2. Matching incentive value between appetitive and aversive outcomes

Experiment 2.1

Introduction

The purpose of the current experiment was to obtain several measures of incentive salience value for aversive and appetitive stimuli varying in subjective intensity level to decide which stimuli to use in subsequent experiments examining mechanisms of attention during learning. Incentive salience can affect learning and attention independent of valence and in order avoid confounds in the attentional data related to differences in motivation it is necessary to match aversive and rewarding reinforcers according to their motivational properties as much as possible. In addition, confirming that subjectively different intensity levels differ according to incentive value will be of use in subsequent experiments when analysing the effects of increasing incentive value on attention.

Drug studies have been the primary source of information regarding the effects of motivation on attention and learning. This is because drug-related stimuli are more personally relevant to drug-users than to non-drug users. Thus, it may be assumed that drug-associated stimuli have higher motivational properties for drug-users than for non-drug users. Smokers have been found to gaze longer at smoking-related pictures when compared to non-smokers (Mogg, Bradley, Field, & De Houwer, 2003). Furthermore, increasing motivation by manipulating internal drive states has also led to increased in attention. When smokers are cigarette-deprived their gaze is maintained for longer on smoking cues relative to smokers who have not been nicotine-deprived (M. Field, Mogg, & Bradley, 2004). As well as effects on attention, increased motivation to obtain a stimulus is also related to increased learning about that stimulus; Bizarro & Stolerman (2003) found that higher motivation for food, as manipulated by prior food restriction, resulted in increased anticipatory responses, fewer omission errors, shorter response latencies and completion of more trials, without compromising on accuracy, in a subsequent 5-serial reaction time task to obtain a food reward. Hanlon, Baldo, Sadeghian, & Kelley (2004) also found that food-deprived rats learnt how to perform an instrumental response to obtain a food reward while food-satiated rats did not, indicating that motivation enhances learning. While these studies all provide evidence for the influence of motivation on learning and attention for rewarding events, the same also applies for the effects of motivation on attention and learning for aversive events. As with smokers, people with specific phobias find phobic-related stimuli more relevant than those without the specific phobia. Rinck & Becker (2006) showed that spider-fearfuls showed faster initial orientation to spider pictures and then avoided them, relative to non-spider-fearfuls. Soares, Esteves, & Flykt (2009) also found that spider-phobics displayed attentional biases to spider pictures, but not to snake pictures, while snake-phobics displayed the opposite effect – demonstrating that the motivation to avoid a stimulus can influence attention in a similar fashion to the way in which appetitive motivations influence attention.

In order to try to match the motivation to obtain an appetitive reinforcer with the motivation to avoid an aversive reinforcer, and to ascertain which intensity levels are discriminated according to their incentive salience a mixture of behavioural and subjective measures of incentive value were obtained. One of the most commonly used behavioural measures of motivation for an appetitive or an aversive outcome is the rate of responding when making an instrumental response to obtain a reward or avoid an aversive event. Appetitive studies have found that increasing sucrose concentration increased the rate of lever pressing to obtain the reward in a VI schedule (Bradshaw et al., 1981; Bradshaw et al., 1978). Fewer studies have manipulated the level of an aversive reinforcer, but there is some evidence that response rate is also a measure of avoidance motivation. One study using squirrel monkeys reported that when the frequency of shocks to be avoided was increased the number of avoidance responses were also increased (Bacotti, 1978). This study used number of responses per second as a measure of the response rate. Indeed, in the current study, due to this relationship, the *number* of responses made was used as a measure of the response rate. However, it was not converted to responses per second as this was only relevant in the Bacotti (1978) study due to comparisons between different reinforcement schedules. An instrumental schedule was required that would induce more than one instrumental response in order to get such a measure of response rate. Variable-interval schedules produce multiple responding for a reinforcer, and therefore seemed an appropriate paradigm to use to obtain the behavioural measures of motivation. As discussed in the general methods section, the variable interval schedule also appears to be a more valid and precise measure of motivation compared to other schedules of reinforcement. Although variable interval schedules in animals tend to use VI schedules of around 30 seconds with approximately 50 reinforcement trials (Bradshaw et al., 1981; Bradshaw et al., 1978; Willis, Van Hartesveldt, Loken, & Hall, 1974) in humans variable intervals as short as 2.5 seconds have been used (Ruddle et al., 1982). However, in this latter study there were still 30 reinforcement trials per reinforcement schedule. As there were to be 6 reinforcement schedules in the current design, it was deemed more appropriate to shorten the number of intervals from 30 to 10 for each variable interval sequence in order to reduce the likelihood of fatigue effects. However, the VI schedule length was increased from 2.5 to 4 seconds, increasing the possibility that differences in response rate between reinforcer types would be detected. Instrumental responding for a reinforcer may also habituate over time. One study found that responses for an appetitive food reinforcer decreased over the first 20 minutes of training (Temple, Giacomelli, Roemmich, & Epstein, 2008). In addition, these investigators found that this decrease was enhanced in a group that was allowed to consume the food they received. Hence, motivation may also affect habituation rates. Motivation to obtain a reward or avoid a punishment may vary over the trials: as rewards are obtained over time their value may decrease, while the motivation to avoid the noise may decrease as the time interval since they last received the noise outcome increases. Furthermore, such habituation rates may vary depending on the type of reinforcer. Thus, it is important to try to obtain a measure of motivation prior to habituation occurring for either of the reinforcers. As there will only be 10 intervals for each reinforcer in the current design, lasting only approximately 1 minute for each reinforcer, this is not comparable to the findings of Temple et al. (2008) where habituation effects were found. However, to ensure that there were no habituation effects for the reinforcers in the current study the response rate was compared during the first and second half of the interval schedules. To minimize confusion it was decided that presentation of the reinforcer schedules would be semi- rather than fully-randomised: variable interval schedules were presented in blocks according to the valence of the reinforcer but the order of intensity was randomised, as was the order of appetitive or aversive reinforcer blocks of schedules.

As well as behavioural measures of incentive value several subjective measures may be helpful in validating the behavioural measures in addition to providing independent evaluations of incentive salience. Validation of the behavioural measures was acquired through subjective ratings regarding the maximum number of times they would be prepared to respond for the reinforcer. While such a response is clearly measuring motivated responding more in accordance with break-point paradigms (where subjects are required to respond increasingly more on every subsequent trial), the rate of responding is not easily subjectively comparable i.e. it is difficult to describe differences in response rate that an individual would be aware of and could verbalise. In contrast, a break-point can be more readily described in quantifiable terms that an individual could relate to. However, as discussed in the general methods section, variable interval and progressive ratio schedules do not yield similar response patterns and may engage different cognitive processes; thus, there may be differences between subjective and behavioural measures of motivation in the current design. A further measure of incentive salience may be acquired through affective ratings of the outcomes. Although this measure may not be used for the purpose of matching between appetitive and aversive outcomes, it provides an additional measure for discriminating levels according to incentive value. That said, it is possible for a discrepancy to occur between subjective affective ratings and instrumental responding measures of incentive salience. For example, when a food reward is devalued, rats will still press a lever to obtain the food until they experience consummation of that food again (Balleine & Dickinson, 1991), indicating that prior to consuming the devalued food the motivational salience of the food is controlling responding, but the hedonic value does not. However, it has been proposed that it is the subsequent hedonic reaction when food is consumed after devaluation that alters the neural representation of the incentive value, consequently leading to a decrease in instrumental responding (Balleine & Dickinson, 1991). Thus, both motivational salience and hedonic value may independently influence responding for incentive stimuli. Thus, while subjective ratings measuring the affective value of the reinforcers therefore provided another indication of incentive salience, as hedonic affect and motivation are independent, it was acknowledged that the behavioural response may become dissociated from the subjective affective response. Another measure of subjective motivation (related to individual motivational traits) may also be obtained from the BIS/ BAS scale developed by Carver and White (1994). As discussed in the general methods section, this scale measures individual differences in sensitivity to rewards and punishments– the behavioural activation system (BAS) and the behavioural inhibition system (BIS), respectively (Gray, 1990). Corr (2002) has proposed that these two systems may have both facilitatory (BIS-punishment, BAS-reward) and antagonist (BIS-reward, BAS-punishment) influences on behaviour. Indeed, Avila, Parcet, & Barros-Loscertales (2008) reported that individuals scoring high on a reward sensitivity scale exhibited decreased brain activity in regions associated with aversive learning during a task that required them to detect aversive “stop” signals whilst responding for rewards. Such effects may be significant to the current study as if there is a tendency for one motivational system to be greater than the other in the participant population, this could both facilitate responding for one class of stimuli while simultaneously decreasing responding for the opponent motivational system. Hence, subjective measures of BIS and BAS were taken in order to eliminate differences in baseline motivational sensitivity as a possible confound.

As there was no particular prediction regarding which subset of the reward scale would be most relevant to the current investigation, reward subsets were combined to create a summed value of BAS. This approach has been used in previous studies using the BIS/BAS scale (McFarland, Shankman, Tenke, Bruder, & Klein, 2006).

The aversive and appetitive reinforcers were blasts of white noise and money respectively. White noise has been successfully used to induce aversive conditioning to a conditioned stimulus at 97db according to emotional ratings (L. Hogarth, Dickinson, Austin et al., 2008) and 102db has likewise induced conditioned avoidance responding (Loeber & Duka, 2009). Hogarth et al. (2008) also used a 92db reinforcer in a parallel study to the 97db reinforcer, and reported that anxiety ratings were higher for the 97db noise over the 92db noise, indicating that 97db has a high incentive value than 92db. Thus, a tentative hypothesis was made that that a 97db noise would induce a greater rate of avoidance responding than a 92db noise. While there has been no such comparison with a 102db reinforcer and other noise intensities in humans, in rats Shankar, Awasthy, Mago, & Tandon (1999) reported that a 102db noise induced higher stress-induced analgesia than a 98db noise. However, the 98db noise was a shrill tone while the 102db was a white noise so whether they induce equivalent differential motivation when both presented as white noise has yet to be ascertained. Money was considered the most appropriate appetitive reinforcer for the current study for reasons discussed in the general methods section. 10p has previously been used in reward-based tasks such as those assessing aspects of probability discounting (Anderson, Richell, & Bradshaw, 2003) while both 15 cents and 5 cents have also been used in similar paradigms (Cherek & Lane, 1999). As instrumental responding differed between these two reinforcers, it was decided that they would be appropriate levels to use in the current paradigm. 15 cents is equivalent to a little under 10p, and 5 cents is equivalent to slightly less than 5p; thus, 5p and 10p were also selected as reinforcers in the current design. 20p has also been used as an appetitive reinforcer (L. Hogarth et al., 2007), indicating that it would be appropriate as the highest level appetitive reinforcer. However, in order to increase the likelihood of discrimination in incentive value from the 10p, 50p was allocated as the highest intensity level for the appetitive reinforcers.

Method

Subjects

12 subjects (6 male) aged between 18 and 38 (SEM 23.08 ± 1.61) participated in the experiment. Subjects were recruited using advertisements sent via email to students and staff at the University of Sussex who were members of a psychology subject pool. Subjects were only permitted to take part in the study if they were over 18 years of age, were not currently taking any psychoactive drugs, not currently diagnosed with an anxiety or depressive disorder, and were in general good health. Subjects gave their informed consent before participating in the study, which was approved by the University of Sussex ethics committee. Subjects received a payment of £6.50 at the end of the experiment regardless of how much money, if any, they had earned during the variable interval schedule.

Design

A 2-way within-subjects design was employed with intensity of outcome (3 levels: low, medium, high) and valence of outcome (2 levels: money, noise) as the within-subject variables. Variable interval training for each outcome was presented in a block of ten trials (i.e. ten reinforcement intervals). Presentation of blocks were semi-randomised such that the 3 noise blocks ran consecutively, and the 3 money blocks ran consecutively, but order of noise blocks or money blocks first was counterbalanced, and the order within the noise and money blocks was also counterbalanced. Allocation to counterbalances was randomised.

Materials

<u>Outcomes:</u> The 92db, 97db, or 102db white noise was administered binaurally through headphones (Sennheiser, PX200) for 40 ms. Ten 10 pence pieces, ten 50 pence pieces, and ten 5 pence pieces were present in three separate open tins to the right hand side of the participant, while an empty tin in which to transfer money was on the left hand side of the participant.

<u>Visual stimuli:</u> 6 different stimuli were used as signals to make the avoidance response. They were developed from images in clipart and can be found in Appendix 1.

<u>Questionnaires:</u> The Behavioural Inhibition Scale and Behavioural Activation Scale (BIS/BAS; Carver and White, 1994) was used to measure baseline motivation sensitivity,

and a medical history questionnaire ascertained that subjects fulfilled all the health-related criteria; both were administered prior to the variable-interval training. This scale may also be found in Appendix 6.

Procedure

Each subject was tested individually in one 30 minute session. This consisted of completion of a consent form and questionnaires which took approximately 5 minutes. Subjects then completed 60 trials of variable-interval training. Each trial lasted approximately 6 seconds for noise outcomes, and approximately 10 seconds for money outcomes.

Initial procedures

Participants completed the consent form, medical history questionnaire, and the BIS/BAS scale

Variable-interval procedure

Participants were seated at a desk in the experimental cubicle, facing a PC with a keyboard in front of them. They also had an open empty tin, and separate tins containing the appropriate amount of money (5ps, 10ps, or 50ps) in front of them on the desk. Participants were presented with the following general instructions for the entire procedure on the PC screen: *"There are 6 blocks associated with either one level of noise or one level of money. In each block you will be presented with a picture signalling that you should press the spacebar many times if you wish to avoid the noise or receive the money (depending on the* *block). At the end of each block you will have to answer some questions. There are 3 different levels of money, and 3 different levels of noise. You will be told at the beginning of each block what the level of money or noise is. Press the spacebar when you are ready to begin."* 10 trials of variable interval training then followed. At the end of each variable interval schedule 3 questions followed to measure subjective ratings of the emotional and motivational properties of the outcomes. This procedure was completed a total of 6 times for the 6 different reinforcers.

Trial sequence for variable interval training

There was an initial presentation phase at the beginning of each block to ensure that participants experienced the outcome at least once. At the beginning of each block participants were first presented with the stimulus for 3000ms before they received the outcome. For noise outcomes a blank screen was presented for a further 3000ms with a 40ms blast of noise. For money conditions a blank background appeared with text indicating the outcome they had received ("*5p*", "*10p*" or "*50p*") for 3000ms. The following instructions then appeared (text presented in bold here indicates that only the appropriate text for that particular block was present): "*The testing session for block **1 OR 2 OR 3 OR 4 OR 5 OR 6** will now begin. Once the picture appears on the screen you need to press the spacebar many times if you wish to **receive 5p OR 10p OR 50p OR avoid 92db OR 97db OR 102db**. Press the spacebar to begin."* Each trial proceeded in the following way: the appropriate stimulus appeared on the screen for 4000ms during which time the participants could press the spacebar as many time as they wished. There was a 100ms time window within the 4000ms time window, where if they pressed the spacebar during this time they would avoid the noise/receive the money at the end of the trial. This 100ms time window was randomly assigned to a time point within the 4000ms stimulus presentation on every trial. For the noise outcomes, if they had pressed within the time window then the stimulus disappeared and the following feedback appeared on the screen for 3000ms *"You have NOT RECEIVED **92db OR 97db OR 102db**"*. If they had failed to press during the time window then the stimulus disappeared and they received 40ms of the noise at the beginning of 3000ms of a blank screen. For the money outcomes if they had pressed within the time window then the stimulus disappeared and the following feedback appeared on the screen for an infinite amount of time *"You have RECEIVED **5p OR 10p OR 50p**. Put **5p OR 10p OR 50p** in your box. Press the ENTER key when you are finished."* If they hadn't pressed within the time window then the stimulus disappeared and they received the following feedback for 3000ms *"You have NOT RECEIVED **5p OR 10p OR 50p**"*. For all outcomes there then followed 2000ms of a blank screen before the next trial began.

Sequence for subjective ratings

Subjects were then presented (in random order) questions regarding the emotionality of the unconditioned stimulus and their perceptions of their motivation regarding the stimuli. To obtain a subjective measure of motivation the stimulus acting as a signal to respond was presented on the screen and participants used the number keys on the keyboard to answer the following question "*What is the MAXIMUM number of times you would press a button (like you just did) in order to **receive/avoid** the **money/noise** associated with this picture? Use the green number keys and the scale below to answer.1 = 0-50, 2 = 50-100, 3 = 100-200, 4 = 200-300, 5 = 300+*". There were two questions measuring the emotionality of the stimulus. To measure how pleasant they found the outcome the same procedure applied but with the following question: *"How PLEASANT do you find the **noise/money** associated with this picture? Indicate the strength of your feeling on a scale of 1 to 9 using the green number keys.1 = not at all pleasant, 9 = extremely pleasant".* Using the same procedure another question measured anxiety for the outcome: *"How ANXIOUS does the **noise/money** associated with this picture make you feel? Indicate the strength of your feeling on a scale of 1 to 9 using the green number keys.1 = not at all anxious, 9 = extremely anxious".*

Statistical analysis

Corrections were made for all of the dependent variables such that any value 3 standard deviations above the mean was replaced with the mean of the level it was entered for analysis. Assumptions of all statistical procedures applied were checked. In the case of violation of the assumption of homogeneity of variances, the Greenhouse-Geisser adjustment was applied and adjusted degrees of freedom are reported. For significant main effects, post-hoc analyses with Bonferroni-corrected t-tests were used. All results were significant at $p<0.05$ unless otherwise stated. All analyses were performed using the Statistical Package of Social Sciences (SPSS 16).

Variables measured during variable-interval training:

Motivation to avoid or gain the stimuli was calculated as the number of times they pressed the spacebar over the entire schedule (i.e. over ten intervals). To ensure that this response did not significantly change over training for any of the outcomes, t-tests were performed on the first 5 trials versus the last 5 trials of VI schedule, for each reinforcer. If there were no differences, all ten trials were collapsed and the mean number of responses made over the ten trials was analysed using a 2-way within-subjects ANOVAs with intensity of outcome (3 levels: low, medium, high) and valence of outcome (2 levels: money, noise) as the within-subject factors.

Variables measured during subjective evaluations of stimuli:

Subjective measures of motivation were obtained using the responses to the question asking the maximum number of responses they would make to receive the money or avoid the noise (1-5 scale). This measure of motivation was analysed using 2-way ANOVAs with intensity of outcome (3 levels: low, medium, high) and valence of outcome (2 levels: money, noise) as the within-subject factors.

Measures of emotionality were obtained from anxiety and pleasantness ratings taken during this phase. Emotionality for the noise reinforcers was assessed using the anxiety ratings, while emotionality for the money reinforcers was assessed using the pleasantness ratings; both of these were analysed using 1-way repeated ANOVAs with intensity of outcome (3 levels: low, medium, high) as the within-subject factor.

Other analyses:

To increase the validity of the behavioural measure of incentive salience, Pearson's correlation coefficients were calculated for emotional ratings and the mean number of responses, and for subjective motivational ratings and the mean number of responses. For the emotional analysis correlation coefficients were calculated between the mean number of responses of the 3 levels of noise and their corresponding anxiety ratings, and between the mean number of responses for the 3 levels of money and their corresponding pleasantness rating.

Likewise, coefficients were calculated between BIS ratings and the mean number of responses collapsed across noise conditions, and between BAS ratings and the mean number of responses collapsed across money conditions in order to eliminate individual differences in baseline motivation as a confound. ..

Results

Participant variables

Table 2.1.1: Variables related to participant characteristics. Values are mean ± S.E.M (range in brackets)

Age	BIS	BAS
23.08 ± 1.61 (18-38)	2.85 ± 0.16 (1.86-3.86)	3.12 ± 0.13 (2.18-3.70)

Variables measures during variable interval responding:

Number of responses:

When differences between the first 5 and last 5 trials for each reinforcer type were analysed using t-tests, there were no significant differences in the mean number of responses for any of the reinforcer types. Hence, any further analysis on the response data was collapsed across all ten trials. Effect sizes ranged from $t(11) = 0.14$, to $t(11) = 1.50$, and p values ranged from $p=0.16$ to $p=0.89$.

Figure 2.1.1 shows the mean number of responses made over each VI schedule. There was a main effect of level only ($F(2,22) = 7.10$, $p<0.05$). Valence ($F(1,11) = 1.58$, $p=0.24$), and valence x level ($F(2,22) = 0.03$, $p=0.97$) effects did not reach significance. Planned contrasts on the main effect of level indicated that there was no significant difference between the low and medium reinforcers ($F(1,11) = 0.33$, $p=0.58$), but there was a significant difference between the medium and high level reinforcers ($F(1,11) = 10.14$, $p<0.05$). Post-hoc t-tests showed that there was no difference between the two low reinforcers ($t(11) = 1.45$, $p=0.18$), no difference between the two medium reinforcers ($t(11) = 1.30$, $p=0.22$), and no difference between the two high level reinforcers ($t(8) = 0.66$, $p=0.52$).

Figure 2.1.1: Number of responses made over ten trials of a 4 second variable interval schedule to obtain a reward (5p, 10, or 50p) or to avoid an outcome (92db, 97db, 102db). Values are mean ± S.E.M

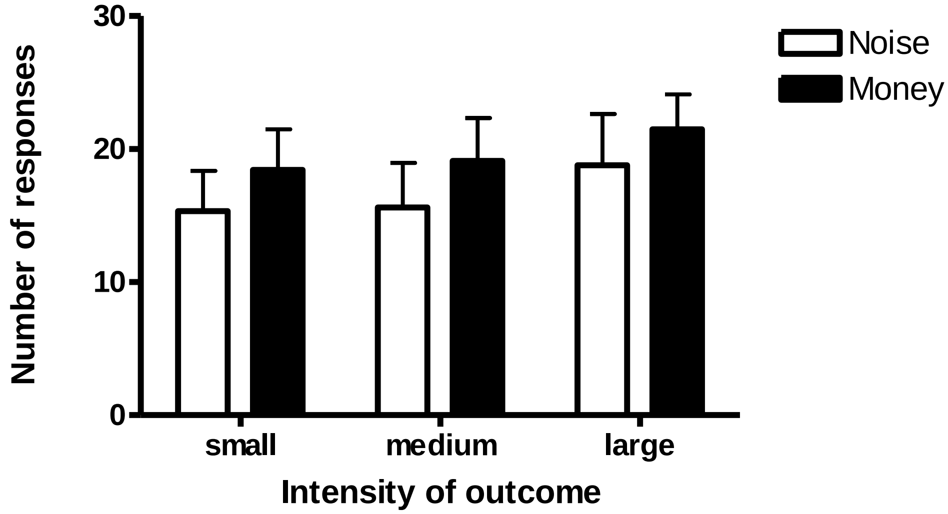


Table 2.1.2 shows the number of trials where at least one bar press response was made for each VI schedule. Post-hoc chi-square analysis performed on each level (low, medium, high) between stimulus valences indicated that there was a significant difference in the number of trials responded to in the 5p and 92db conditions ($\chi^2(1) = 4.09$, $p<0.05$), and more trials were responded to in the 50p condition compared to the 102db condition ($\chi^2(1) = 9.23$, $p<0.05$), while there was no significant difference between the number of trials responded to for the 10p and 97db conditions.

Table 2.1.2: Number of trials during the variable interval schedule where at least one bar press response was made, shown separately for each outcome

Outcome	Number of trials a response was made (out of 120)
92db	87
97db	91
102db	96
5p	100
10p	102
50p	112

Table 2.1.3 shows the number of trials on which responding was reinforced for each type of outcome. A post-hoc chi-square analysis was performed on each level (low, medium, high) between stimulus valences, and revealed that there was no significant difference in the number of reinforced trials between 92db and 5p ($\chi^2(1) = 2.41$, $p=0.12$), there were more reinforcements in the 10p condition compared to the 97db condition ($\chi^2(1) = 4.82$, $p<0.05$), but there was also no difference at all in the number of reinforcements between the two highest reinforcers ($\chi^2(1) = 0.00$, $p=1.00$).

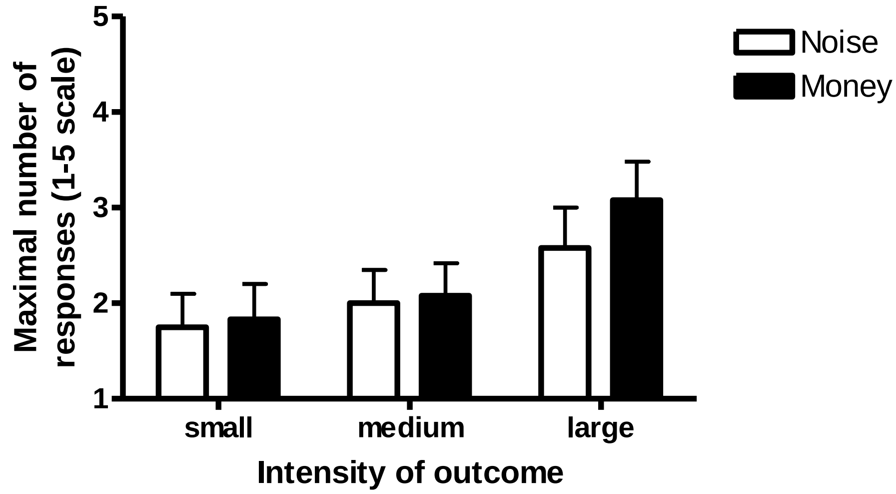
Table 2.1.3: Number of times a bar press response was reinforced through either receiving money or avoiding the noise, shown separately for each outcome

Outcome	Number of reinforced trials (out of 120)
92db	51
97db	52
102db	67
5p	63
10p	69
50p	67

Variables measured during subjective evaluations of stimuli:

Subjective motivation: Figure 2.1.2 shows the mean maximum number of times participants would make a bar press response in order to obtain the money or avoid the noise. There was a main effect of level only ($F(2,22) = 11.31$, $p<0.05$), where there was no significant difference between low and medium levels of reinforcer ($F(1,11) = 2.20$, $p=0.17$), but there was between medium and high levels of reinforcer ($F(1,11) = 9.48$, $p<0.05$).

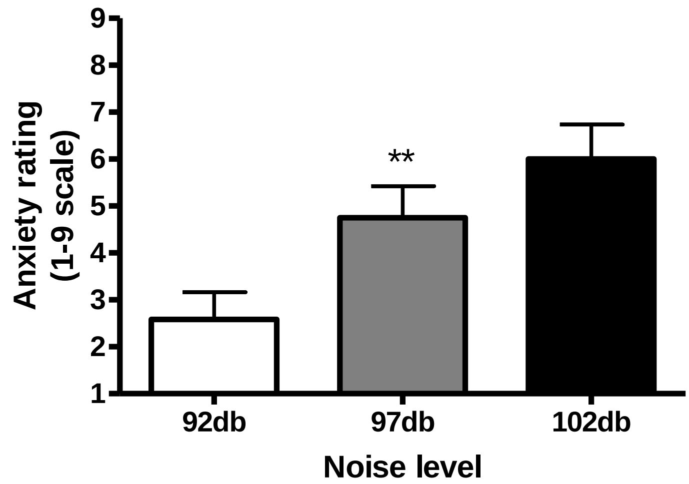
Figure 2.1.2: The maximum number of times the participant would make a bar press response to receive the money or avoid the noise rated on a 1-5 Likert scale. Values are mean ± S.E.M



Emotional responding:

Anxiety ratings (noise only): Figure 2.1.3 shows the mean anxiety ratings for each of the aversive outcomes. There was a main effect of stimulus ($F(2,22) = 11.90$, $p<0.05$), where planned contrasts indicated there was a significant difference between 92db and 97db ($F(1,11) = 9.73$, $p<0.05$) and between 97db and 102db ($F(1,11) = 5.39$, $p<0.05$).

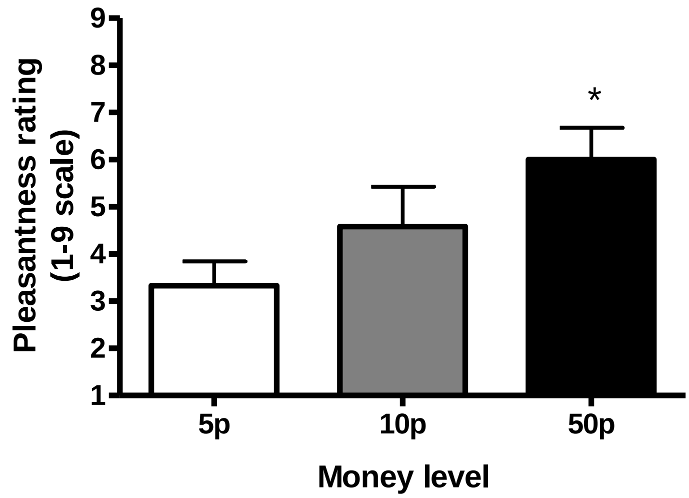
Figure 2.1.3: Subjective anxiety ratings on a 1-9 Likert scale for each of the noise outcomes. Values are mean ± S.E.M



* = p<0.05 compared to both 92db and 102db

Pleasantness ratings (money only): Figure 2.1.4 shows the mean pleasantness ratings for each of the rewarding outcomes. There was a main effect of stimulus ($F(2,22) = 9.56$, $p<0.05$), where there was no significant difference between 5p and 10p ($F(1,11) = 2.10$, $p=0.18$), while there was a significant difference between 10p and 50p ($F(1,11) = 10.63$, $p<0.05$).

Figure 2.1.4: Subjective pleasantness ratings on a 1-9 Likert scale for each of the noise outcomes. Values are mean ± S.E.M



*** =** p<0.05 compared to 10p

Other Analyses:

Relationship between VI responses and subjective ratings:

Emotion: There was a borderline significant correlation between anxiety ratings and the number of responses made for the noise outcomes ($r = 0.32$, $p=0.06$) and no significant correlation for pleasantness ratings and the mean number of responses for the money outcomes ($r = 0.12$, $p=0.50$).

Subjective motivation: There was no correlation between subjective motivation ratings and the mean number of responses ($r = 0.14$, $p=0.23$).

Relationship between baseline motivation and VI responding:

For the collapsed noise conditions there was no significant correlation between BIS and the mean number of responses ($r = 0.11$, $p=0.74$).

For collapsed money conditions there was no significant correlation between BAS score and the mean number of responses made ($r = -0.30$, $p=0.35$).

Discussion

In general, behavioural measures indicated that the incentive values of the reinforcers were equivalent between valences for each level of reinforcer intensity. Behavioural measures indicated that more responses were made in the presence of the high intensity reinforcers (102db and 50p) compared to the medium intensity reinforcers (97db and 10p), while the number of responses made was greater for the medium intensity reinforcers compared to the low intensity reinforcers (92db and 5p). These findings support the data that a 102db noise is more aversive than a 98db noise (102db of a shrill tone induced a greater unconditioned stress responses than either a 98db tone) (Shankar et al., 1999). This effect also indicated that 50p was more motivating than 10p, which had not yet been indicated in any study so far. Motivated responding was of an equivalent value for the 5p and the 10p conditions, which appears to contradict the findings of Cherek & Lane (1999), who reported that 15 cents was a greater reinforcer than 5 cents. However, the design varied in several aspects from the present study: their procedure was a forced choice task where a response was made for either the 5 cents after a fixed 5 second delay, or for 15 cents after a variable delay between 5 and 7 seconds. Such a design may be measuring impulsivity (indeed, this was the purpose of the study) rather than motivation, and hence could account for the discrepancy with the present findings. The lack of a difference between 92db and 97db in terms of responding does appear to contrast with reports from Hogarth et al. (2008) where anxiety ratings were greater for the 97db white noise over the 92db white noise. However, no behavioural measures of incentive value were obtained during this earlier study, and as previously discussed, the emotionality of a reinforcer alone may not necessarily control instrumental responding (Balleine & Dickinson, 1991).

Subjective ratings, for the most part, also supported the findings from the behavioural measures of motivation. Self-reported break-points exactly matched the pattern of effects for number of responses – there was no difference between the valence of the reinforcer, while high level reinforcers had higher break points than medium level reinforcers, with no differences between low and medium intensity reinforcers. Likewise, anxiety ratings were greater for the 102db over the 97db, while pleasantness ratings were greater for the 50p compared to the 10p reinforcer, indicating that the higher intensity reinforcers had a higher incentive value. However, while pleasantness ratings indicated that there was no significant difference in affective value between the 10p and 5p, in line with the behavioural response, anxiety was significantly greater for the 97db over the 92db noise, which does not match the pattern of behavioural responding. In addition, while the emotional pattern of results for appetitive stimuli appeared to match the behavioural findings, further correlations revealed that there was no relationship between emotional ratings and the number of responses for any of the reinforcers. As described in the introduction, both motivational and affective properties of a reinforcer are important components in determining the incentive value of a reinforcer (Balleine & Dickinson, 1991), and as such, it is possible for a dissociation to occur between affective ratings and motivational responding. However, these results are surprising considering other studies have found that the appetitive affective value of a stimulus is related to approach responses. For example, Bradley, Field, Healy, & Mogg (2008) reported that both the affective value of the smoking cues (pleasant or unpleasant) and the motivational salience (drug-relevance to individual) influenced the approach bias – appetitive smoking cues increased approach biases in both smokers and non-smokers, while unpleasant smoking cues induced greater approach biases in smokers relative to non-smokers. However, emotion has been conceptualised along two dimensions: “arousal” and “valence”. Fmri data has shown that valence and arousal of emotional stimuli activate different areas of the brain (Lewis, Critchley, Rotshtein, & Dolan, 2007), indicating that these two components of emotion may be governed by different processes. Thus, in the present study, the emotional ratings may only reflect the valence component of emotion, rather than arousal, and this may explain the lack of a relationship between emotion and motivated responding. The final measure of incentive value of the outcome, subjective motivational ratings, also failed to correlate with the number of responses made. However, differences in sensitivity of these measures may be responsible for the absence of a correlation.

BIS and BAS scores, a measure of individual differences in appetitive and aversive motivation did not correlate with the number of responses, eliminating baseline differences in motivation as a confound in the current study. However, the lack of a relationship between BIS and BAS scores and the behavioural measures used in the current design may also be related to BIS/BAS scores reflecting only one aspect of motivation. BIS and BAS scores relate to *general* biases in motivation, while the behavioural response used in the present design was related to a *specific* motivational response. As studies on outcome-specific and general Pavlovian-to-instrumental transfer (PIT) have shown, general motivation, and motivation for specific reinforcers is governed by separate processes; Corbit & Balleine (2005) demonstrated that there was a double dissociation between the effects of lesions on the basolateral amygdala (BLA) and central nucleus of the amygdala (CN) on general and outcome-specific PIT. Rats were initially trained to associate a pellet and a sucrose reward with two different stimuli, and then underwent training to make different instrumental responses in order to receive the pellet and sucrose rewards. BLA lesions abolished the outcome-specific effects but spared the general motivational effects of the pavlovian cues. In contrast, lesions of the CN abolished the general motivational but spared the specific effects of these cues. Thus, general-motivational, and outcome-specific effects appear to be mediated by separate systems, and this could account for the absence of a relationship between BIS/BAS scores and behavioural responses.

While in general the results supported a matching in incentive salience for all of the intensity levels regardless of valence, there was some discrepancy between valences in the number of trials where a response was made, implicating that these levels were not evenly matched in incentive value. Post-hoc analysis revealed that while 10p and 97db had an equivalent number of trials on which a response was made, the appetitive reinforcers for the high and low levels (50p compared to 102db, and 5p compared to 92db respectively) yielded responses on a greater number of trials than the aversive reinforcers of the same level. This appears to indicate that 5p had a greater incentive value than 92db, while 50p had a higher incentive value than 102db. However, additional analysis also revealed that the number of successful reinforcements for these levels were equivalent, suggesting that in general for the noise outcomes participants pressed on less occasions, but when they did press, they pressed just as vigorously as for the rewards. This discrepancy in behavioural strategies could be related to the concept that action initiation and sustained responding are mediated by different processes. Niva (2007) posited that while initial action selection is mediated by phasic Dopamine signals, response rate is influenced by tonic Dopamine responses, such that it is possible for a discrepancy to occur between these two measures. Thus, it is possible for a discrepancy to occur between initial action selection, and sustained responding. Why the majority of initial responses should be made for the reward schedules over the aversive schedules is unclear, but different neural substrates are believed to govern appetitive and aversive instrumental responding, which may be relevant to this disparity. Indeed, Daw, Kakade, & Dayan (2002) have presented evidence that phasic DA codes for appetitive prediction errors, whilst phasic 5HT codes for aversive prediction errors. In the context of the current study, this theory implies that as different neural substrates are involved in the initiation of a response (5HT for aversive outcomes, DA for reward outcomes), this may account for the differences in the current study between appetitive and aversive responses in terms of the number of trials where a response was made - responding may not be completely matched between rewards and punishments as they rely on different neural substrates that may have different response-dependent profiles, and may be dominated by different instrumental mechanisms. In addition, unlike nonhuman responding on variable-interval schedules, responding in humans may also be rule-governed as well as being mediated by the contingency between responding and reinforcement rate. Horne & Lowe (1993) conducted a series of variable-interval experiments on humans where post-experimental verbal reports from the participants on behavioural strategies employed during responding was often more closely related to the response rate than the rate of reinforcement. Thus, in humans there may be additional rules and cognitive strategies deployed that control motivated responding, and which are not accounted for in the current study. The instigation of such rules may also be related to the apparent differences in behavioural responding strategies for the aversive and appetitive outcomes, as negative and positive affect have been known to differentially influence cognitive processing. For example, Gasper & Clore (2002) reported that positive mood enhanced global processing of visual information, while negative mood enhanced local processing of visual information. Thus, in the current study different moods induced by the appetitive and aversive schedules may have differentially affected cognitively-mediated behaviours. That said, in the absence of any additional supporting data, such conclusions must remain purely speculative.

The conclusion that all intensity levels were matched according to motivation must also be regarded with caution as the *frequency* of reinforcement was slightly greater for the noise outcomes over the money outcomes (this was due to the additional time taken on money trials to transfer the money, and was thus unavoidable). Studies have demonstrated that increasing the frequency of reinforcement, usually via a smaller variable interval schedule, increases the response rate (Catania & Reynolds, 1968). Thus, the money outcomes may be higher in incentive value to their corresponding level of noise outcome than actually indicated by response rates in the current study. Despite this confound, subjective and emotional ratings were generally supportive of the behavioural findings, increasing their validity. However, as only the 97db and 10p reinforcers also had an equivalent number of trials which were responded on, they are likely to be the most well-matched in terms of motivation, given that it appears that a similar behavioural strategy was employed at this level.

3. Attention for conditioned stimuli during learning for an appetitive or an aversive outcome

Experiment 3.1

Introduction

The purpose of the current study was to investigate to what extent attention for a stimulus that was predictive of an affective outcome, would be mediated by the acquired affective properties or the predictive certainty of that stimulus. The emotionality hypothesis for aversive outcomes is based on the extensive literature demonstrating that stimuli associated with a threat tend to induce vigilant behaviour; principally manifested as enhanced attention for stimuli (Van Damme, Crombez, Eccleston, & Goubert, 2004; Van Damme, Lorenz et al., 2004). Likewise, the addiction literature appears to predict that attention for stimuli predictive of rewarding outcomes should also be dominated by the appetitive properties of that stimulus (Robinson & Berridge, 1993; Stewart et al., 1984). However, for both scenarios there is a discrepancy in the literature, whereby some studies have demonstrated that regardless of the valence of the outcome, attention for a stimulus predictive of an outcome is governed by the prediction error produced. In aversive learning Hogarth, Dickinson, Austin, Brown, & Duka (2008) reported that attention for an aversive CS+ decreased after learning had occurred, while attention for a partial predictor (CS+/-) continued to be attended to. Similar results were reported for an appetitive conditioning paradigm using rats with food as the appetitive outcome (Kaye & Pearce, 1984). However, there is not a comparable human study with appetitive outcomes to support this data. Replication of the Hogarth et al. (2008) study but with an additional appetitive outcome would provide much needed support for the prediction error hypothesis as mediating reward learning. In addition, the time period during which attention was measured in the original paradigm with the aversive outcome may have biased attention towards the partial predictor. Indeed, the finding that attention is greater for a partial predictor over a full predictor has yet to be replicated in the aversive conditioning literature. An attempt to alleviate this confound will also be addressed in the current design.

In order to investigate whether attentional biases were mediated by different processes in aversive and appetitive learning, a visual conditioning paradigm was employed replicating a design used by Hogarth et al. (2008). As prediction error and emotional theories of attention make differing predictions concerning the allocation of attention, a Pavlovian conditioning paradigm should be able to elucidate which of these processes is having the greater influence on attention. In this design a CS+ (100% predictive of outcome), a CS+/- (50% predictive of outcome), and a CS- (0% predictive of the outcome) are presented as part of a pair (neutral stimulus X) over a number of trials and the progression of attention and learning are measured. According to emotional theories attention should be greatest for the CS+ over both the CS+/- and CS- at the end of conditioning, while according to theories of prediction error attention should be greatest for the CS+/- at the end of conditioning (once learning of the CS+ has occurred). Expectancy questions will be used to measure learning as per the original design. However, it was decided to make some adaptations to the design in order to further elucidate some of the mechanisms involved in attention.

Baseline emotional measures of the conditioned stimuli at the beginning as well as at the end of conditioning were included to help clarify the relationship between emotion and attention. Prior similar studies examining the relationship between attention and learning had only used post-conditioning measures of emotionality (L. Hogarth, Dickinson, Austin et al., 2008; L. Hogarth, Dickinson, Hutton, Bamborough et al., 2006), which may not have fully captured the conditioned emotional response. Additional emotional conditioning trials will be included prior to the main discriminative training phase employed in the original design in order to detect whether the progression of emotional response and attentional bias to conditioned stimuli are matched. Changes in emotionality across conditioning should match changes in attention if attention is influenced by emotion, while if there is a mismatch between the progression of attention and emotion this will invalidate such a conclusion. In order to obtain a measure of early emotional conditioning subjects will undergo a small amount of conditioning but in the absence of high cognitive demand, i.e. without having to answer a question regarding expectancy for the outcome. 8 presentations of conditioning for each stimulus (CS+, CS+/-, and CS-) should be sufficient to induce an emotional response without learning reaching asymptote. Studies that have used skin conductance responses (eg. GSR) to obtain a measure of emotional arousal have reported that an emotional response may be obtained after a relatively short number of trials - (Hamm, Greenwald, Bradley, & Lang, 1993) conducted a study where visual stimuli acted as the CS+ and CS- in an aversive conditioning paradigm for an electric shock. They found that 8 conditioning trials (4 for CS+, 4 for CS-) were sufficient to induce a differentiation in arousal as measured by skin conductance response, while there was also a greater acceleratory heart rate response for the CS+ over the CS-. In addition, subjective ratings taken after a subsequent extinction phase, indicated that the CS+ was still rated as more unpleasant than the CS-. However, the type of conditioned stimuli used in this paradigm were aversive affective stimuli and, in accordance with preparedness theory, this may have enhanced the acquisition of the conditioned emotional response (Ohman, 1986). While in the current design non-affective stimuli served as the conditioned stimuli, the findings of the Hamm et al. study still provide a useful starting point for the number of trials required to elicit an emotional response. Thus, in the current design, 8 presentations for each of the 3 stimuli should be sufficient for some level of emotional conditioning to occur, while allowing for a full counterbalance of outcomes. While it cannot be assumed that some level of explicit knowledge of the outcome will not be obtained due to this procedure, the absence of the expectancy question during this phase, which has been shown to prompt learning - continuous prompting of expectancies on a trial-by-trial basis has been demonstrated to lead to increases in correct responses on post-experimental contingency-awareness questionnaires (Dawson & Biferno, 1973) - should aid in delaying the acquisition of full declarative knowledge of the outcomes.

One further manipulation of the original design was included in order to address the issues with the measure of attention occurring prior to making an expectancy response, which may have created a confound in the original design. Attention during this phase may be biased towards top-down processes that may mask any influences of emotion. Studies have found that when top-down control strategies are imposed, this can bias attention according to these goals (Bacon & Egeth, 1994; Leber & Egeth, 2006). Thus, the goal of answering the question may override any attentional processes mediated by emotion or prediction error, and an anticipatory phase may reveal a purer measure of attention. Therefore, in addition to measuring attention as per the original design (from stimulus onset to the expectancy response) attention was measured after they had made their expectancy rating (the CS will be presented for a further 3 seconds prior to the outcome occurring). In particular, such a measure may be more associated with attention mediated by emotion. Anticipation of increasing monetary rewards has been shown to be linearly associated with increasing activation in reward processing areas such as the nucleus accumbens (Knutson, Adams, Fong, & Hommer, 2001) while anticipation of aversive events are also associated with the increased activation of areas associated with emotional processing such as the amygdala (Knippenberg, van Luijtelaar, & Maes, 2002). Thus, in the current design, attention was examined separately for the period of time prior to providing an expectancy rating (as per the original design), and during an anticipatory period before the outcome had occurred to measure attention to stimuli unconfounded by cognitive processes related to providing an expectancy response. Other than these additional changes, the number of trials and the visual stimuli used remained true to the original design.

As well as the measures of emotionality and expectancy, attention was measured throughout the conditioning procedure. As discussed in the general methods section, attentional mechanisms may be conceptualised as being composed of two components – initial capture of attention (which may reflect a combination of automatic and controlled processes) and sustained attention (a pure measure of controlled processes). Hence two measures of attention were employed that would reflect these different processes – dwell time bias, and likelihood of first fixation (where likelihood of first fixation reflects the early capture of attention, and dwell time reflects controlled attention – see introduction for more details). Whether mechanisms of learning and emotion preferentially control one of these aspects of attention is inconclusive. However, there is evidence that they have a role in both. Studies have found that emotional stimuli are more likely to be oriented to first and have a higher number of subsequent fixations compared to neutral stimuli (Nummenmaa et al., 2006a). EEG experiments have found similar results where emotional words induce greater amplitudes for event-related negativity (Herbert et al., 2008a), while greater amplitudes are also present for the P300 (a component associated with the orientation of attention) for emotional over neutral stimuli (Schupp et al., 2007). These results suggest that attention is oriented to faster for emotional stimuli. In addition, emotional stimuli may hold attention for longer than non-emotional stimuli. When positive picture scenes were presented as a pair with neutral picture scenes and viewed for 3 seconds, subject's initial fixation durations were longer for positive compared to neutral pictures (Caseras et al., 2007), and Buodo, Sarlo, & Palomba (2002) reported that aversive blood-injury stimuli interfered with a concurrent cognitive task up to 4000 ms after initial stimulus presentation. While the Buodo et al. study did not measure eye-movements it may be inferred that a similar effect would have been observed had such measures been obtained. The length of time a stimulus is attended to may be related to the emotional properties of that stimulus, but it may also reflect enhanced processing of stimuli related to its predictive value. Wills, Lavric, Croft, & Hodgson (2007) found that greater dwell times were spent on neutrally-affective stimuli with higher prediction errors compared to those with smaller prediction errors. Dwell time has also been shown to be greatest for conditioned stimuli with the highest prediction error in a version of the current paradigm (L. Hogarth, Dickinson, Austin et al., 2008). Thus, as attention according to prediction error and attention according to emotion have different predictions regarding sustained attention, dwell time is a useful measure for testing whether emotion or prediction error dominates attention. There is less clear evidence regarding whether prediction errors will also influence the likelihood that the stimulus will be attended to first as, to the authors knowledge, there is no eye-tracking data in support of this. According to Pearce and Hall (1980) stimuli are automatically attended to when the outcome is fully predicted, while uncertain predictors elicit controlled attentional processes. However, findings from EEG studies do seem to imply that stimuli associated with large prediction errors may also attract attention automatically. Wills et al. (2007) reported greater N1 amplitudes for stimuli associated with a high prediction error compared to stimuli associated with a lower prediction error. As the N1 is associated with pre-conscious automatic processing of stimuli, it may be inferred that attention will be automatically drawn to such stimuli. Although it is not known whether likelihood to first fixation will also be influenced by prediction error (it may not be a pure measure of automatic attention), it will still be a useful tool in the current design in order to validate the dwell time measure of attention. It will also be a useful tool to test the vigiliance-avoidance hypothesis (Mogg, Bradley et al., 2004), that aversive stimuli will initially capture attention, but then they will be avoided. If such an event occurs in the present investigation, then attentional bias should be present for the aversive CS+ according to likelihood of first fixation, while dwell time bias should reveal a subsequent avoidance.

Finally, the behavioural and subjective data from experiment 2.1 indicated that 97db was closely matched with 10p in terms of motivational properties. This is important in the current design as attention has been shown to be enhanced when the motivational properties of the stimuli are likewise enhanced (Franken et al., 2000; Lubman, Allen, Peters, & Deakin, 2007). As a result, 10p and 97db were chosen as the respective appetitive and aversive unconditioned stimuli, in order to avoid main effects between these groups becoming masked through differences in motivation.

Although the Hogarth et al. (2008) study reported that the conditioning procedure using a 97db outcome appeared to adhere to prediction error rules, there was a major confound within the study, which cast doubt onto the validity of the findings. In the original study the time period in which attention was measured may have been affected by top-down mechanisms as attention was measured prior to the expectancy ratings being made. The current design endeavoured to investigate this proposal by measuring a separate time window of attention – after an expectancy rating had been made, but prior to the outcome occurring. Attention, after the demands of the task have been met, may be less confounded by goal-driven mechanisms and therefore may give a better measure of attention as driven by emotional processes. Thus, in the current study, it was hypothesised that attention for the aversive stimulus would produce attentional effects that matched the emotionality of the stimulus. During the anticipatory time window dwell time bias should indicate that there will be an increase in attention for the CS+ as learning progresses and that dwell time bias for the CS+ will always be greater than for the CS+/-. In addition, there will be no attentional bias for the CS-. This pattern of attention data should match the measures of emotionality: overall anxiety ratings should be of the order CS+>CS+/->CS-, while anxiety levels for the CS+ should increase as learning progresses. There is no such directly comparable study for a reward outcome on which to base predictions for the monetary outcome. Kaye & Pearce (1984) reported similar findings to the Hogarth et al. (2008) study, but they used rats and a food reward. In contrast, conditioning studies in humans have shown that attention for a conditioned stimulus predictive of a rewarding drug outcome does not diminish after learning (L. Hogarth, Dickinson, Hutton, Elbers et al., 2006; L. Hogarth, Dickinson, Janowski et al., 2008), which concurs with emotional rather than prediction error mechanisms. Therefore, the hypotheses for conditioned stimuli in the rewarding condition mirror the predictions outlined for the aversive outcome. If predictions are incorrect, and attention is mediated by prediction error, dwell time bias should decrease for the CS+ after learning but should remain high for the CS+/-. Such changes in dwell time should be independent of the emotional response, which should indicate that emotional conditioning had occurred in the order of CS+>CS+/->CS-.

Method

Subjects

32 subjects (16 male) aged between 18 and 50 (SEM mean 24.72 ± 1.38) participated in the experiment. Subjects were recruited using advertisements sent via email to students and staff at the University of Sussex who were members of a psychology subject pool. Subjects were only permitted to take part in the study if they were over 18 years of age, had no hearing difficulties, were not currently taking any anti-depressants, and were in general good health. Subjects gave their informed consent before participating in the study, which was approved by the University of Sussex ethics committee. Subjects received a payment of £5 at the end of the experiment.

Design

For the majority of measures a 3 way mixed design was employed. The within-subject variables were CS type (3 levels: CS+, CS+/-, CS-) and block (2 level: block 1, block 2), and the between-subject variable was the valence of the outcome (2 levels: 10p or 97db). Allocation of subjects to either the 10p or 97db outcome condition was randomised. Subjects in both conditions completed 24 trials of emotional conditioning followed by 144 trials of discriminative training.

Materials

Conditioned stimuli: The four visual abstract stimuli used as the conditioned and context stimuli can be found in the Appendix 2.

Outcome: The 97db white noise was administered binaurally through headphones (PX200 Sennheiser) for 40 ms. For the money condition ninety 10 pence pieces were present in an open tin to the right hand side of the participant, while an empty tin in which to transfer money was on their left.

Eye-tracking: Eye movements were tracked using an Eyelink II eye tracker (SR Research Ltd. 5516 Main St., Osgoode, Ontario, Canada K0A 2W0. <http://www.eyelinkinfo.com>). Eye movements were measured on every trial throughout both phases of conditioning.

Questionnaires (see Appendix 6):

Medical History Questionnaire

This ensured that the participants were in general good health and were not currently taking any anti-psychotic medication.

The Profile of Mood States

For the purpose of the current study it was used to measure participant's current anxiety and depression level.

The Behavioural Inhibition Scale and Behavioural Activation Scale

This provided a score for with which to measure behaviour activation (BAS) and behavioural inhibition (BIS).

All questionnaires were administered prior to conditioning.

Visual Acuity: In order to ensure that participants would be able to discriminate between the visual stimuli they took the Snellen 3-m visual acuity test to make sure their eyesight was at a minimum level of 20/30. This is a chart that consists of rows of letters that the participant is required to read aloud while standing 3 metres away from the chart. Participants had to be able to read the letters at the 20/30 level in order to take part in the study.

Procedure

Each subject was tested individually in one 50 minute session. This consisted of using the Snellen 3m acuity test to ensure visual eligibility and completion of consent form and questionnaires which took approximately ten minutes. The second part consisted of firstly calibrating the eyetracker device (approximately 5 minutes), 24 trials of emotional conditioning trials, and 144 trials of declarative conditioning trials, with each trial lasting approximately 10 seconds. The conditioning procedure and reinforcement contingencies were the same during both the emotional and the declarative phases although subjective rating scales differed (see below).

Initial procedures

Participants' visual acuity was tested using the Snellen acuity test. Participants then completed the consent form and questionnaires.

Emotional conditioning procedure

CS+, CS+/- and CS- stimuli were presented as part of a picture pair with a context stimulus "X" eight times each with the side of the screen they appeared on counterbalanced. For half of the trials, presentation of the stimulus was followed by the question "How pleasant do you find this stimulus? 1 = not at all pleasant, 9 = extremely pleasant". For the other half of the trials, presentation of the stimulus was followed by the question "How anxious does this stimulus make you feel? 1 = not at all anxious, 9 = extremely anxious". The questions were randomised and participants responded using any of the keys 1 to 9.

Declarative conditioning procedure

CS+, CS+/- and CS- were presented as part of a picture pair with a context stimulus "X" 48 times each in a randomised order again with counterbalanced side of screen presentation. For the noise condition, after each presentation of the stimulus participants were required to answer the question "How likely is it you will hear a loud noise? 1 = not at all likely, 9 = extremely likely" where they used any of the keys 1 to 9 to answer. For the money condition they answered the question “How likely is it you will receive 10p? 1 – not at all likely, 9 = extremely likely”. Presentation of the stimuli was divided up into 12 blocks of 12 trials where order of presentation was randomised within each block of 12. This was done in order to minimise the number of consecutive presentations of the same stimulus pairs.

Stimulus contingencies (for both emotional and declarative conditioning phases)

Four visual stimuli predicted differing probabilities of the outcome occurring. When stimulus A was on the screen it predicted that the outcome would occur 100% of the time (CS+), when stimulus B was on the screen it predicted that the outcome would occur 50% of the time (CS+/-), and when the C stimulus appeared on the screen it predicted that the outcome would occur 0% of the time (CS-). X was a control stimulus and appeared as part of a stimulus pair in conjunction with A, B, or C.

Trial sequence (for both emotional and declarative conditioning phases)

Each trial proceeded in the following way: a fixation cross appeared in the centre of the screen and once the pupil was fixated on the centre of the cross the experimenter pressed the space bar on a separate computer and the cross disappeared to be replaced by a stimulus pair and a question. For the emotional conditioning phase this was the anxiety or pleasantness question, and for the declarative training phase this was the expectancy question. Once subjects had responded the question would disappear and there was a further 3 seconds with just the picture pair on the screen. For the noise condition there then followed either a 40ms noise or 40ms silence, followed by a further 2 seconds of the picture pair stimulus alone. For the money condition there was either presentation of the words "You have received 10p. Put 10p into your box. When you have finished press ENTER." or presentation of the words "You have not received 10p. Do not put 10p into your box. When you have finished press ENTER." followed by 2 seconds of the stimulus pair alone once they had pressed the ENTER key. This was changed from the original Hogarth et al. (2008) paradigm where the outcome could occur within a variable interval of 1-5 seconds after an expectancy rating had been made. This change was made in order to more accurately match the timing of the outcome between the money and noise conditions. There was no inter-trial interval, and the following trial immediately commenced with the fixation cross.

Post-training emotional evaluation

At the end of discriminative conditioning participants were presented with the CS+, CS+/-, CS- and context stimulus X, where each stimulus was presented on it's own twice. For half of the presentations the stimulus was presented with an anxiety question, and for the other half they were presented with a pleasantness question; both of which were the same as the questions presented in the emotional conditioning phase. This was done at the end of conditioning to ensure that emotional conditioning had occurred for both outcomes. Once again, order of presentation of stimuli and question were randomised.

Statistical analysis

Corrections were made for all of the dependent variables such that any value 3 standard deviations above the mean was replaced with the mean of the level it was entered for analysis. Assumptions of all statistical procedures applied were checked. In the case of violation of the assumption of homogeneity of variances, the Greenhouse-Geisser adjustment was applied and adjusted degrees of freedom are reported. For significant main effects, post-hoc analyses with Bonferroni-corrected t-tests were used. All results were significant at $p<0.05$ unless otherwise stated. All analyses were performed using the Statistical Package of Social Sciences (SPSS 16).

Exclusion criteria: Participants were excluded from the subsequent analysis if they failed to become explicitly aware of the contingencies. If the mean expectancy rating was statistically significantly higher for CS+ trials than for CS- trials during the final 36 blocks then participants were labelled as contingency-aware and included in the analysis. Data for the unaware participants can be found in Appendix 2.

Questionnaires: Differences in anxiety, depression, age, BIS, and BAS variables between money and noise groups were analysed separately using independent t-tests, in order to eliminate them as possible confounds between groups.

Attentional variables (declarative conditioning only): Dwell time was initially calculated as the total time a stimulus was attended to on a given trial. As the amount of time the stimuli were presented could vary, it was further transformed as a percentage of the total time the stimulus was presented for on that trial and log ten transformed. Dwell time bias scores for each predictive stimulus type were then calculated by subtracting the transformed context stimulus from the transformed predictive stimulus. The likelihood of first fixation was transformed into the following ratio for each conditioned stimulus: ***(number of times***

predictive stimulus fixated to first – number of times context stimulus fixated to first) / (number of times predictive stimulus fixated to first + number of times context stimulus fixated to first).

For the declarative conditioning phase only both dwell time bias scores and likelihood to first fixation ratios were analysed using a 3-way ANOVA with UCS type as the between-subjects factor (2 levels: money/noise) and CS type and block as the within-subject factors (3 levels: CS+, CS+/-, CS-; and 2 levels: block 1, block 2).

Learning variables (declarative conditioning phase only): Expectancy ratings were analysed using a 3-way ANOVA with UCS type as the between-subjects factor (2 levels: money/noise) and CS type and block as the within-subject factors (3 levels: CS+, CS+/-, CS-; and 2 levels: block 1, block 2).

Emotional conditioning variables: For the noise stimuli the anxiety ratings were used, while for the money condition the pleasantness ratings were used. During the initial emotional conditioning phase the final emotional rating score provided for each of the stimuli was used, while the emotional scores provided post-training were also used. Emotional conditioning for noise and money conditions was then analysed separately using a 2-way ANOVA with within-subject factors stimulus (3 levels: CS+, CS+/-, CS-) and block (2 levels: pre-training, post-training).

Other analyses:

The relationship between learning and emotion was examined by calculating Pearson's correlation coefficients between the mean value of anxiety for the CS+ (noise condition) and the mean dwell time bias for both time windows (i.e. pre and post expectancy ratings), while Pearson's correlation coefficients were also calculated between the mean value of pleasantness for the CS+ (money condition) with the mean dwell time bias for the CS+ during both time windows.

Results

Exclusion criteria:

In accordance with the contingency-awareness criteria, no subjects were excluded from the noise condition, while 2 males were excluded from the money condition. The subsequent analysis is on the remaining 30 participants. All data for the unaware participants is presented in Appendix 2.

Questionnaires:

Table 3.1.1 shows the mean values, SEM and ranges of several variables related to emotion and motivation. In order to ensure there were no between-group differences in these variables that may have confounded the results obtained, a series of t-tests were performed on these data using type of outcome as an independent variable. There were no significant differences between groups on any of these variables ($t < 0.85$, $p > 0.40$).

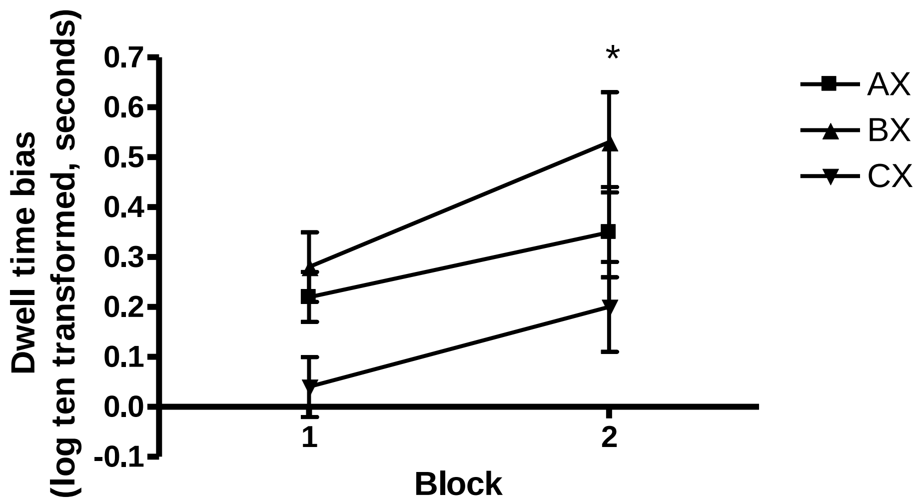
Table 3.1.1 Variables related to emotional and motivational baselines of participants in the money and noise conditions. Values are means ± SEM (range in brackets)

	Noise	Money
Age	26.13 ± 1.90 (19-43)	23.64 ± 2.27 (18-50)
Anxiety	0.50 ± 0.14 (-0.22-1.67)	0.45 ± 0.18 (-0.33-2.00)
Depression	0.44 ± 0.09 (0.00-1.20)	0.50 ± 0.15 (0.00-1.67)
BIS	3.12 ± 0.12 (2.14-3.57)	3.18 ± 0.12 (2.43-4.00)
BAS	3.39 ± 0.11 (2.40-4.00)	3.43 ± 0.08 (3.00-4.00)

Attentional variables (declarative conditioning only):

Dwell time (1^{st} phase, between stimulus onset and expectancy response): There was a main effect of block ($F(1,28) = 10.84$, $p<0.05$), indicating that overall dwell times increased from block 1 (0.18 ± 0.05) to block 2 (0.36 ± 0.08). Figure 3.1.1 shows the increase in attention for each of the three stimuli over block.

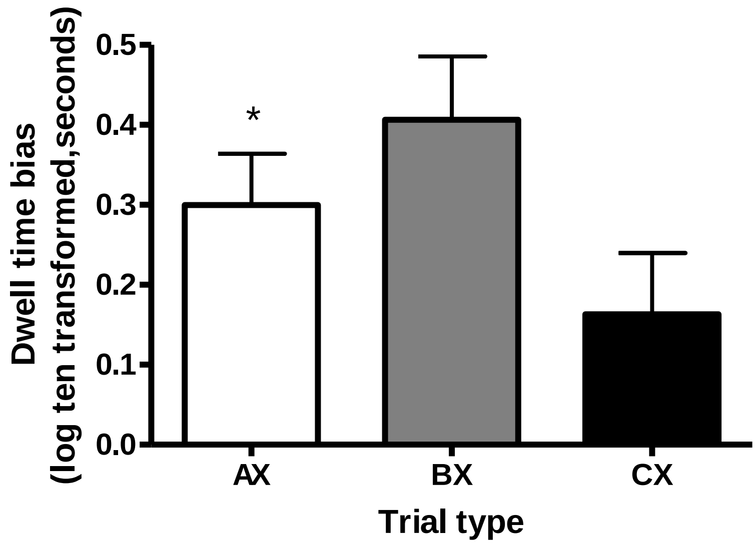
Figure 3.1.1: Dwell time bias scores during the declarative conditioning phase obtained in the first time window between stimulus onset and expectancy response on AX, BX and CX trials, and separated into two blocks. Values are mean ± SEM



* = p<0.05 for AX, BX, and CX compared between block 1 and 2

Figure 3.1.2 shows that there was also a main effect of stimulus (F(2,56) = 11.70, p<0.05) where planned contrasts indicated that there was a borderline difference between A and B (F(1,28) = 3.85, p=0.06) and a significant difference between A and C (F(1,28) = 6.54, p<0.05). Post-hoc t-tests comparing the stimuli to zero revealed that dwell time for stimulus A (t(29) = 4.66, p<0.05), stimulus B (t(29) = 5.13, p<0.05), and stimulus C t(29) = 2.13, p<0.05), were all significant from zero.

Figure 3.1.2: Dwell time bias scores collapsed across 97db and 10p outcomes,obtained in the declarative learning trials during the first time window between stimulus onset and expectancy response for A-AX, B-BX, C-CX trials. Values are mean ± SEM



*= p<0.05 compared to CX

Although there was not a condition x stimulus interaction, mean dwell time bias values for each stimulus in the separate conditions are depicted in table 3.1.2.

Table 3.1.2: Dwell time bias scores obtained in the declarative learning trials during the first window between stimulus presentation and expectancy response for AX, BX, CX trials with 97db and 10p outcomes. Values are mean ± SEM

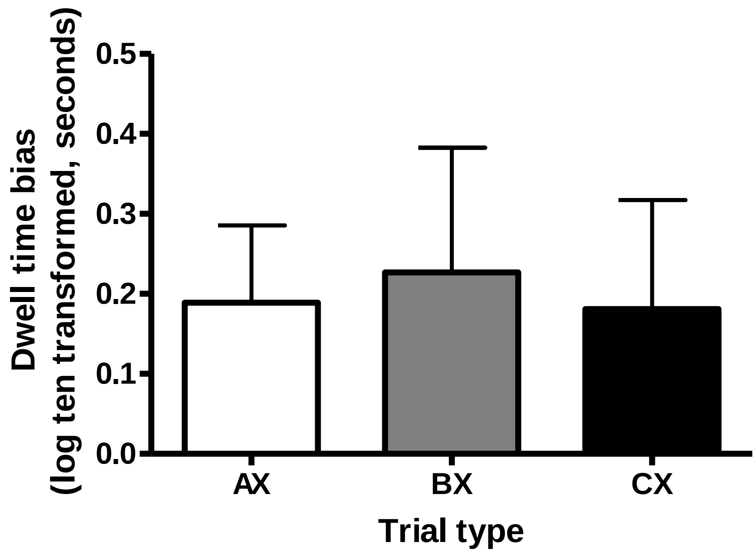
	AX	BX	CX
97db	0.32 ± 0.09	0.51 ± 0.11	0.22 ± 0.11
10p	0.28 ± 0.09	0.28 ± 0.10	0.09 ± 0.11

Dwell time (2nd phase, between expectancy response and outcome): There was no main effect of stimulus, no stimulus x condition interaction, no stimulus x block interaction, and no stimulus x block x condition ($F < 1.12$, $p > 0.33$). However, for the purposes of comparison with the first measure of dwell time, mean dwell time bias for each stimulus is depicted in Figure 3.1.3.

There was a main effect of condition however ($F(1,28) = 14.60$, $p < 0.05$), indicating that overall there was a greater dwell time bias for stimuli in the money condition (0.51± 0.14) than for stimuli in the noise condition (-0.07 ± 0.07).

Post-hoc t-tests comparing the mean dwell time bias for each stimulus to zero found that A was borderline different from zero ($t(29) = 1.96$, $p=0.06$), while B and C were not significant from zero ($t<1.46$, $p>0.15$).

Figure 3.1.3: Dwell time bias scores collapsed across 97db and 10p conditions,obtained in the declarative learning trials during the second time window between expectancy response and outcome for AX, BX, CX trials. Values are mean ± SEM



Although there was not a condition x stimulus interactions, mean dwell time bias values for each stimulus in the separate conditions are depicted in table 3.1.3.

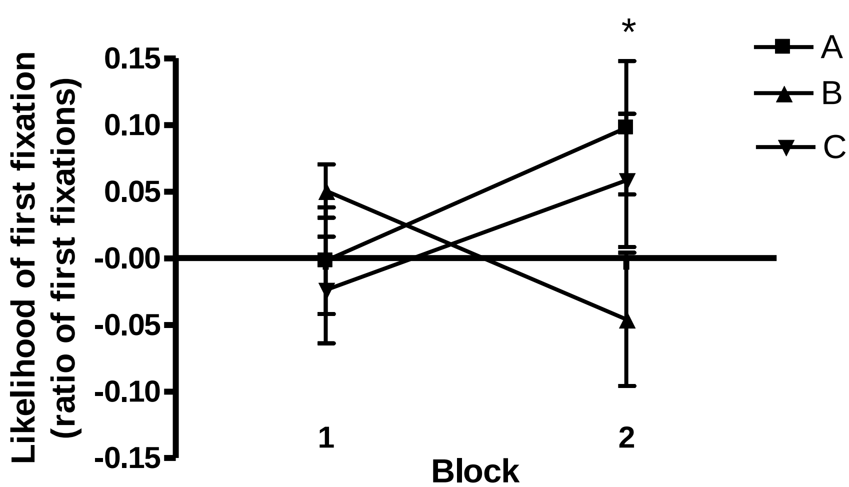
Table 3.1.3: Dwell time bias scores obtained in the declarative learning trials during the second window between expectancy response and outcome for AX, BX, CX trials with 97db and 10p conditions. Values are mean ± SEM

	AX	BX	CX
97db	0.04 ± 0.09	-0.17 ± 0.13	-0.05 ± 0.16
10p	0.40 ± 0.17	0.69 ± 0.25	0.45 ± 0.21

Likelihood of first fixation: There was a main effect condition ($F(1,28) = 5.94$, $p<0.05$) indicating that overall the money stimuli (0.08 ± 0.04) were more likely to capture attention first compared to the noise stimuli (-0.03 ± 0.02).

Figure 3.1.4 shows that there was also a stimulus x block interaction ($F(2,56) = 4.26$, $p<0.05$) where planned contrasts indicated a significant interaction between A and B ($F(1,28) = 5.41$, $p<0.05$), but not between A and C ($F(1,28) = 0.10$, $p=0.45$). However, t-tests failed to show significant differences over block for A, B or C ($F<1.84$, $p>0.07$). Further post-hoc analysis revealed that this interaction was due to a lack of a significant difference between A and B in block 1 ($t(29) = 1.13$, $p=0.27$), while there was a significant difference between A and B in block 2 ($t(29) = 2.06$, $p<0.05$).

Figure 3.1.4: Likelihood ratios that the predictive stimulus (A,B, or C) will be fixated to before the context stimulus X, collapsed across 10p and 97db conditions, during the declarative conditioning phase and split into two blocks. Values are mean ± SEM



* = $p<0.05$ post-hoc test of A compared to B in block 2

Although there was not a condition x stimulus interactions, mean likelihood to first fixation ratios for each stimulus in the separate conditions are depicted in table 3.1.4.

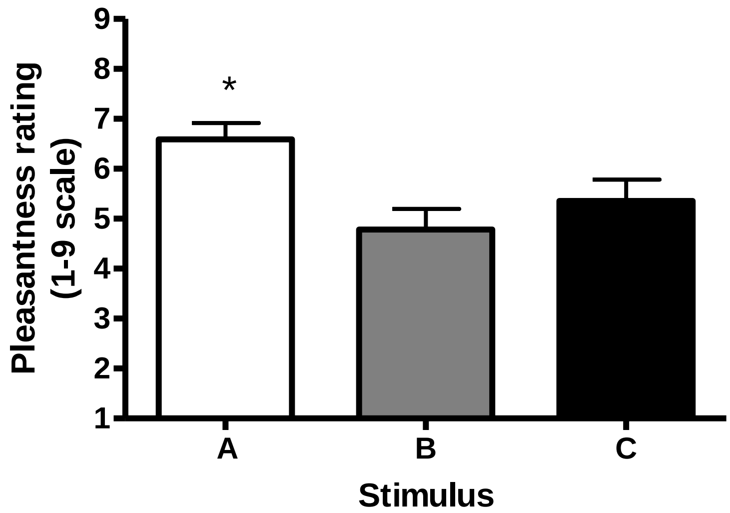
Table 3.1.4: Likelihood ratios that the predictive stimulus (A,B, or C) will be fixated to before the context stimulus X, during the declarative conditioning phase for the 97db and 10p conditions. Values are mean ± SEM

	A ratio	B ratio	C ratio
97db	-0.04 ± 0.04	-0.02 ± 0.03	-0.02 ± 0.04
10p	0.15 ± 0.06	0.03 ± 0.04	0.06 ± 0.07

Emotional conditioning variables:

Money pleasantness: There was a main effect of stimulus ($F(2,26) = 5.28$, $p<0.05$), where A and B were significantly different ($F(1,13) = 13.18$, $p<0.05$), and the difference between A and C was borderline significant ($F(1,13) = 4.26$, $p=0.06$). This effect is depicted in Figure 3.1.5.

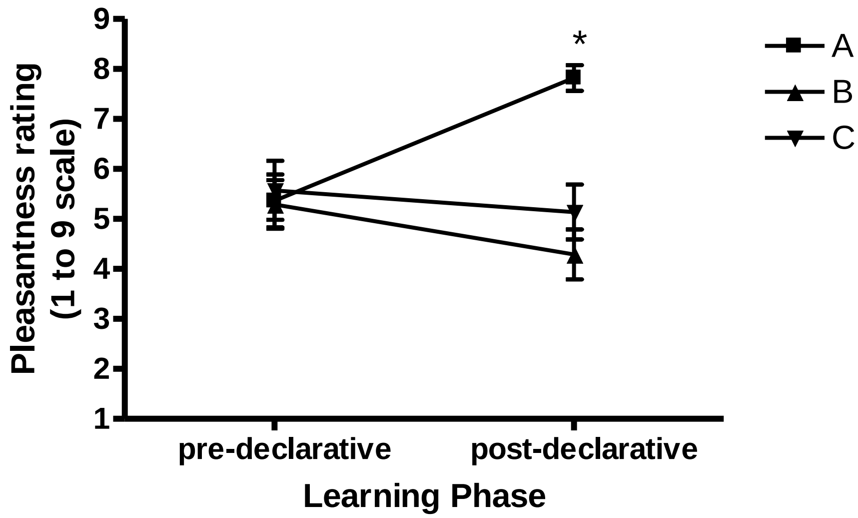
Figure 3.1.5: Pleasantness ratings for stimuli A, B, and C collapsed between the final rating in the emotional conditioning phase, and the rating obtained after declarative training. Values are mean ± SEM



* = $p<0.05$ compared to B, and $p=0.06$ compared to C

Figure 3.1.6 shows that there was also a stimulus x block interaction ($F(2,26) = 8.07$, $p<0.05$) where there was a significant difference between A and B ($F(1,13) = 16.21$, $p<0.05$) and between A and C ($F(1,13) = 7.10$, $p<0.05$). T-tests indicated that there was a significant increase in pleasantness for A over block ($t(13) = 4.89$, $p<0.05$), but there was no change in pleasantness for B or C over block ($t<1.85$, $p>0.08$).

<u>Figure 3.1.6: Pleasantness ratings for stimuli A, B, and C shown as the last rating in the emotional conditiong phase (pre-declarative), and the rating made after the declarative training phase for the 10p condition. Values are mean ± SEM</u>

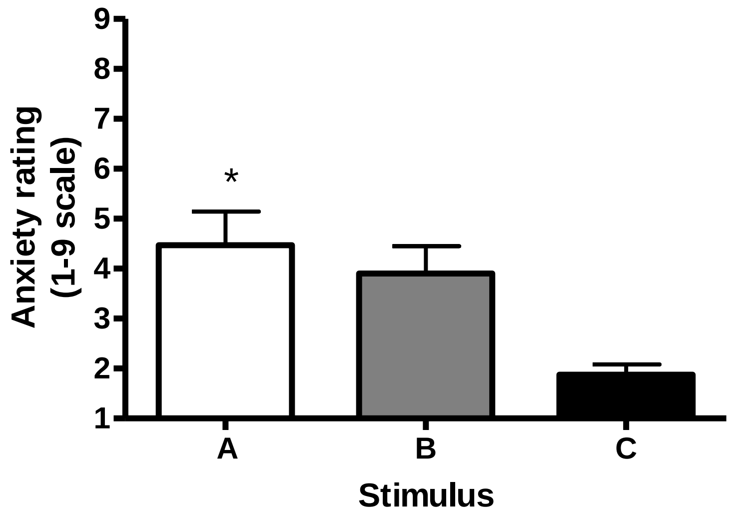


* = p<0.05 for A over learning phases

<u>Noise anxiety:</u> There was a main effect of block ($F(1,15) = 6.16$, $p<0.05$) where there was a general increase in anxiety from block 1 (3.10 ± 0.43) to block 2 (3.74 ± 0.42), irrespective of the stimulus.

There was a also a main effect of stimulus ($F(2,30) = 12.42$, $p<0.05$), where contrasts indicated that there was no significant difference between A and B ($F(1,15) = 1.16$, $p=0.30$), but that there was between A and C ($F(1,15) = 18.52$, $p<0.05$). This effect is depicted in Figure 3.1.7.

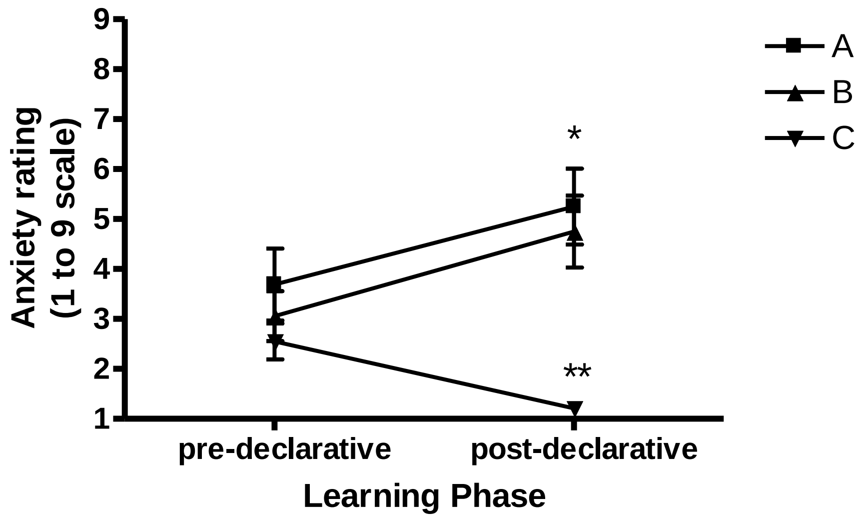
Figure 3.1.7: Anxiety ratings for stimuli A, B, and C collapsed between the final rating in the emotional conditioning phase, and the rating obtained after declarative training. Values are mean ± SEM



* = p<0.05 compared to C

Figure 3.1.8 shows a stimulus x block interaction ($F(2,30) = 9.25$, $p<0.05$), which indicates that A and B elicited the same pattern of anxiety responses over block ($F(1,15) = 0.02$, $p=0.88$) while there was a significant difference between A and C anxiety ratings over block ($F(1,15) = 15.21$, $p<0.05$). T-tests indicated that A increased over block ($t(15) = 2.58$, $p<0.05$) as did B ($t(15) = 2.86$, $p<0.05$), while C decreased over block ($t(15) = 3.90$, $p<0.05$).

Figure 3.1.8: Anxiety ratings for stimuli A, B, and C shown as the last rating in the emotional conditioning phase (pre-declarative), and the rating made after the declarative training phase for the 97db condition. Values are mean ± SEM



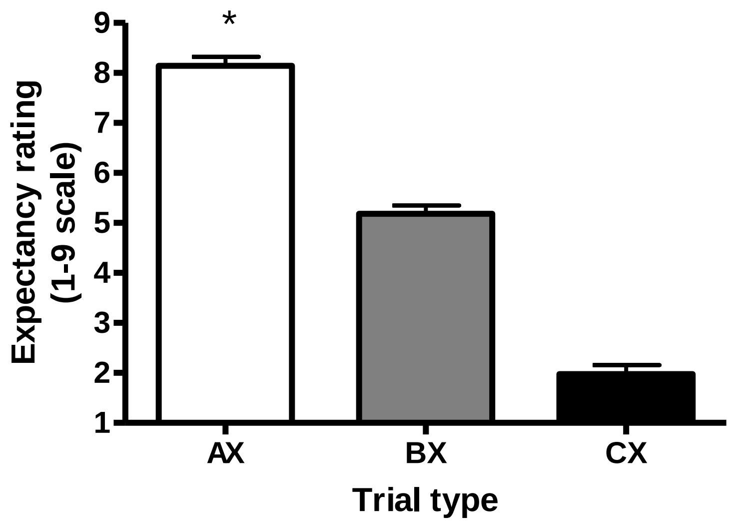
* = p<0.05 for stimulus A and B between learning phases

** = p<0.05 for stimulus C between learning phases

Learning variables (declarative conditioning phase only):

Expectancy ratings: There was a main effect of stimulus ($F(2,56) = 306.23$, $p<0.05$), where A was greater than B ($F(1,28) = 140.21$, $p<0.05$) and A was greater than C ($F(1,28) = 507.39$, $p<0.05$). Mean values for this effect are depicted in Figure 3.1.9.

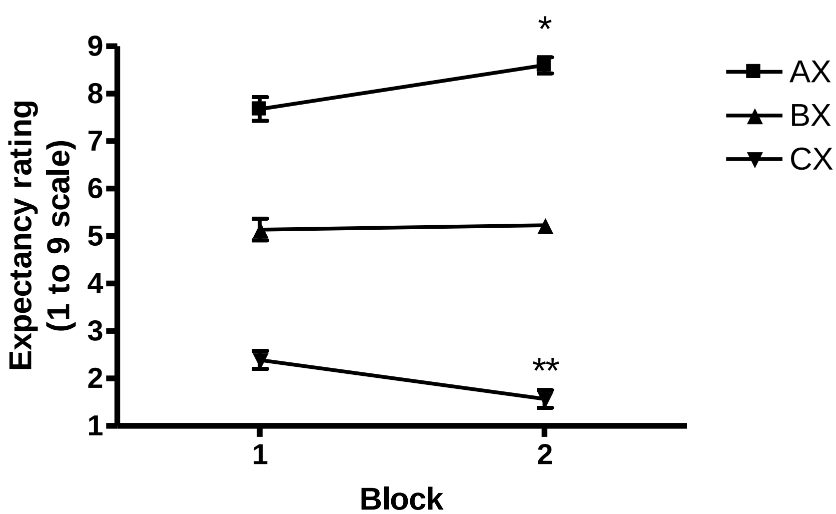
Figure 3.1.9: Expectancy ratings during trials AX, BX, and CX collapsed over 97db and 10p conditions, and collapsed across blocks. Values are mean ± SEM



* = p<0.05 compared to BX and CX

Figure 3.1.10 shows a stimulus x block interaction ($F(2,56) = 476.30$, $p<0.05$) where there was a significant difference between A and B ($F(1,28) = 6.42$, $p<0.05$), and between A and C ($F(1,28) = 43.14$, $p<0.05$). T-tests indicated that A increased over block ($t(29) = 4.40$, $p<0.05$), B did not change over block ($t(29) = 0.50$, $p=0.62$), and C decreased over block ($t(29) = 6.28$, $p<0.05$). Figure 3.1.11 shows that there was also a stimulus x condition interaction ($F(2,56) = 9.89$, $p<0.05$) indicating that while there was not a significant interaction between A and B expectancy between conditions ($F(1,28) = 0.19$, $p=0.67$) there was a significant interaction between A and C ($F(1,28) = 10.80$, $p<0.05$). When the interaction was broken down between conditions, in the noise condition there was a significant stimulus effect ($F(2,30) = 476.30$ where there was a significant difference between A and C ($F(1,15) = 1188.28$, $p<0.05$). In the money condition there was also a significant interaction (F(2,26) = 65.06, p<0.05) and A and C were also significantly different (F(1,13) = 96.00, p<0.05). Thus the interaction must be related to the stronger effect size in the noise condition. Post-hoc t-tests were conducted, and confirmed this hypothesis – although there was no significant difference between conditions for A expectancy (t(28) = 1.77, p=0.09), expectancy on C trials was greater in the money condition (t(28) = 3.95, p<0.05).

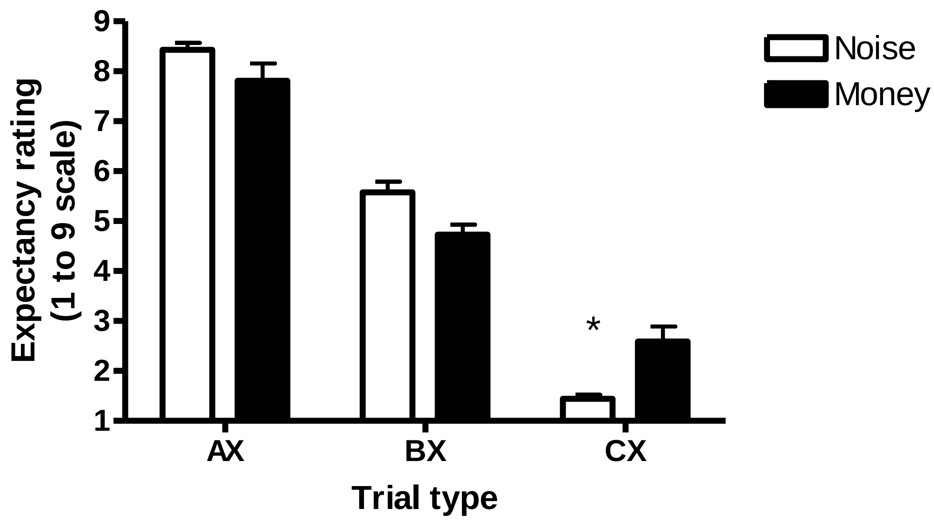
Figure 3.1.10: Expectancy ratings during trials AX, BX, and CX, collapsed across 97db and 10p conditions, during the declarative learning phase and split into two blocks. Values are mean ± SEM



* = p<0.05 compared to AX in block 1

** = p<0.05 compared CX in block 1

Figure 3.1.11: Expectancy ratings during trials AX, BX, and CX for 97db and 10p conditions, collapsed across blocks. Values are mean ± SEM



* = p <0.05 compared to CX in the money condition

Further post-hoc t-tests were conducted on the first expectancy ratings in the declarative conditioning phase to see if learning discrimination had already occurred after the additional 24 emotional conditioning trials. The difference between A (6.40 ± 0.38) and C (4.00 ± 0.39) was significant ($t(29) = 4.54$, $p<0.05$) at this stage, indicating that learning discrimination had already occurred before the declarative conditioning stage had commenced.

Other analyses:

Emotion and dwell time bias in the money condition: For the money condition there was no significant correlation between mean pleasantness ratings for the CS+ and the mean dwell time bias for the CS+ during the first or second time windows when attention was measured ($r = 0.17$, $p=0.57$; $r = 0.10$, $p=0.73$, respectively).

Emotion and dwell time bias in the noise condition: For the noise condition there was also no significant correlation between mean anxiety rating for the CS+ and mean dwell time bias for the CS+ during either the first or second time windows ($r = 0.23$, $p=0.26$; $r = 0.04$, $p=0.08$, respectively).

Discussion

At face value the findings appear to favour a Pearce and Hall (1980) account of attention, although there are some discrepancies with the predictions based on this model and the current findings. The manipulation to induce a purer measure of attention (obtaining a measure of attention after the expectancy response had been made) failed to induce discriminatory stimulus effects; the failure of this measure will be discussed in greater detail in due course. Therefore, the focus of the present discussion on attention relates to attention as measured in the original design (i.e. attention measured between stimulus onset and the expectancy rating response).

Regardless of whether the outcome was noise or money, there was a trend for attention to be greatest for the stimulus with the highest prediction error (the CS+/-) over the full predictor (CS+). This appears to be in accordance with theories of prediction error, as they state that the most uncertain stimulus should yield the greatest amount of attention (Pearce

& Hall, 1980). However as well as not reaching statistical significance, there are several aspects of the data that do not fit this theory. According to prediction error theories, attention for the CS+ should decrease after learning of the outcome has occurred, so the absence of a decrease in attention for the CS+ is problematic for the hypothesis that attention for the CS+ was determined by prediction error. In addition, there was an attentional bias for the CS+ over the CS- throughout the conditioning procedure. This is also problematic for the Pearce and Hall theory (1980) as prediction error for the CS+ and CS- should be at an equivalent level by the end of conditioning. The lack of a decrease in attention to the CS+ after learning, together with the enhanced attention to the CS+ relative to the CS-, implies that some element of emotionality may also have been driving attention.

Although in general the present findings appear to support those of the original study (Hogarth et al. 2008), there are some discrepancies in the findings. Firstly, there was no evidence of a decrease in attentional bias for the CS+, which was present in the original study. In fact, an attentional bias for the CS+ appeared to be present throughout training in the current study, while in the original paradigm attention decreased to the CS+ after learning had occurred. This discrepancy could be due to a major methodological difference in the current study: there were 24 extra trials at the beginning of the current study, which may have enhanced the rate of learning and thus the subsequent decrease in attention to the CS+ may have been lost. Indeed, post-hoc analysis appeared to indicate that some element of learning discrimination had already occurred by the end of these additional 24 trials. Alternatively, as during the additional 24 trials participants were prompted to evaluate the emotionality of the conditioned stimuli, attention may have become biased towards emotional properties, resulting in a continued bias for the CS+ in the subsequent declarative conditioning phase.

An incentive account of attention where the aversiveness of a stimulus (Van Damme, Crombez et al., 2004; Van Damme, Lorenz et al., 2004) or the rewarding qualities of a stimulus (Stewart et al., 1984), mediate attention was not supported by the current findings. For the money condition, overall pleasantness ratings did not match the pattern of dwell time biases as there was a significant difference in pleasantness between the CS+ and CS+/- in pleasantness ratings that was not mirrored in the dwell time bias. In the noise condition, there was no difference between anxiety ratings for the CS+ or CS+/. As with the money outcome, such findings did not match the trend for a greater dwell time for the CS+/- over the CS+. In addition, while emotionality increased over block for the CS+ in both conditions, there was no concurrent increase in dwell time for this stimulus. Correlations confirmed this hypothesis as attention for the CS+ for both outcomes was not related to the emotionality of the stimulus. However, the continued attentional bias to the CS+ over the CS- may partially reflect the engagement of attention according to emotionality. Furthermore, the intensity level of the money and noise may have been too low to induce attention as driven by incentive mechanisms. Certainly, there is some indication that this may be the case for the noise outcome as the mean anxiety rating for the 97db CS+ was relatively low. This possibility needs to be addressed in an additional study using unconditioned stimuli of a greater incentive salience.

The alternative measure of attention, likelihood to first fixation, also failed to support the emotionality hypothesis of attention, apparently contradicting studies reporting that emotional stimuli are more likely to attract attention over non-emotional stimuli (Nummenmaa et al., 2006a). The present findings indicated that the CS+ and CS- were more likely to attract attention as learning progressed, while the CS+/- was less likely to attract attention first as learning progressed. This does not support the emotionality hypothesis, as attention to the CS- also appeared to increase over block. The alternative emotionality hypothesis for the aversive stimuli that the CS+ would be automatically attended to and then avoided (Mogg, Bradley et al., 2004) (the vigilance-avoidance hypothesis), was also not supported by this measure of attention due to the lack of a differentiation between the CS+ and CS-. However, there was some evidence that this measure of attention reflected emotionality as all predictive stimuli in the money condition were more likely to be fixated to first than stimuli in the noise condition. This could reflect either general avoidance strategies in the noise condition, or generalised attraction of attention in the money condition. In the absence of an additional neutral control condition it is impossible to differentiate such hypotheses. In contrast, these trends in the initial allocation of attention appear to support the prediction error hypothesis. According to Pearce and Hall (1980), as the outcome of a stimulus becomes known attention switches from controlled to automatic processes. This is supported by the current data as attention was drawn equally to the two stimuli where the outcome was known and had the lowest prediction error (the CS+ and CS-), while attention was drawn to the CS+/- as the outcome was still uncertain.

While both measures of attention, therefore, appear to support attention as dominated by error-driven mechanisms, the ability of the participant to control the length of stimulus duration in the first time window through making an expectancy response may have created a biased measure of attention for uncertainty. That is, dwell times may have been less for the CS+ and CS- compared to the CS+/- because participants were motivated by making an expectancy response, and less time was required in order to decide what expectancy response to make for the CS+ and CS-. Indeed, Hogarth, Dickinson, & Duka (2009) reported that when stimulus presentation was for a fixed time period attention did not decrease for the CS+ over time (indicating that attention reflected prediction error), whereas when stimulus presentation varied according to when the participant made the expectancy response (as in the current design) attention decreased for the CS+ over time. Thus, the measure of attentional bias during the first time window may have been confounded by the ability of the participant to control the length of the time window in which attention was measured. The lack of significant attentional data obtained during the time window after the expectancy response was made may also be due to this confound. Once an expectancy response was made attention no longer needed to be directed to any of the predictive stimuli. This interpretation is supported by the finding that in general, dwell time biases during this secondary time window were not significant from zero.

A final limitation of the current study was the use of procedures more related to delay conditioning as opposed to a trace conditioning procedure. These procedures may influence attention differentially. In delay conditioning procedures the conditioned stimulus and the unconditioned stimulus co-occur, while in trace conditioning procedures there is a delay between the offset of the conditioned stimulus and the onset of the unconditioned stimulus. According to the findings of one study, attention-distracting stimuli interfere with trace but not delay conditioning in mice (Han et al., 2003). Another study on humans reported similar findings (R. M. Carter, Hofstotter, Tsuchiya, & Koch, 2003), where increasing working memory load during conditioning interfered more when the procedure was a trace design than when it was a delay design, implying that attention may be a more important mediator of learning in trace but not during delay designs. Thus, the design used in the present study is flawed as it may not have sufficiently activated learning-mediated mechanisms of attention, and this may account for the continued bias to the CS+. Trace conditioning designs should be employed in future studies in order to test hypotheses regarding whether attention for a conditioned stimulus is mediated by prediction error learning mechanisms, or by the acquired incentive properties of the stimulus.

4. The effect of increasing the incentive value of the outcome on attention for conditioned stimuli

Experiment 4.1

Introduction

The purpose of the current study was to continue to investigate mechanisms of attention during associative learning, and to eliminate confounds encountered in the previous chapter. The results described in the prior chapter (experiment 3.1) appeared to most closely accord with the prediction error hypothesis (Pearce & Hall, 1980). Attention as measured by dwell time was greatest overall for the stimulus associated with the highest prediction error (the CS+/-). However, there was a major confound in this study as attentional data may have been confounded as the time window in which attention was measured was dependent on the length of time it took the participant to make an expectancy response. Trials on which the outcome was known (CS+ and CS-) did not require a long time in order to know whether or not to make a response, while trials on which the outcome was uncertain (CS+/-) were allocated more attention as it was unclear what response to make and an expectancy response took longer. Such findings accord with previous research, demonstrating that when participants can control the viewing time for a stimulus that is associated with a reward (CS+), attention to this stimulus will diminish, while when stimulus duration is fixed attention does not diminish as learning progresses (L. Hogarth et al., 2009). Thus, the attentional data in the previous study may have created an attentional bias for the uncertain stimulus because the speed of participants' expectancy responses influenced the time window in which attention was measured. Consequently, attention as driven by the incentive properties of the stimuli may have been masked. To diminish the influence of such responses on attention, the stimuli in the present study were presented for a fixed period of 3000ms (this was the period of time used in the aforementioned Hogarth et al. (2009) study) prior to the participant making an expectancy rating.

A further confound may have prevented attention from reflecting incentive-driven mechanisms. These mechanisms of attention may not have been sufficiently activated in the previous study. Indeed, there are previous reports that extreme negative pictures attract more attention than mildly negative pictures (Mogg et al., 2000), while erotic stimuli are also attended to more than less arousing pleasant stimuli (Lang et al., 1993). In order to address the possibility that the unconditioned stimuli in experiment 3.1 were not of a sufficient incentive value to induce incentive-mediated attention, additional higher intensity levels of stimuli were used. 102db and 50p were chosen as the higher levels of noise and money respectively as in experiment 2.1 (see chapter 2) behavioural and subjective affective responses indicated they had a higher incentive value than the 10p and 97db outcomes. In order to ensure that the higher intensity levels used in the current design do indeed have a higher incentive value than the lower intensity outcomes (in accordance with the findings in chapter two) incentive values of the outcomes were assessed both prior to and after the conditioning trials. As with the prior study, appetitive or aversive motivation for the outcome was measured using a variable interval schedule, while the affective value of the unconditioned stimulus was measured using subjective affective ratings. Behavioural measures of the incentive value of the outcome were obtained in addition to the affective ratings as they may reflect slightly different components of incentive value – subjective pleasantness ratings measuring hedonic affective value, and behavioural responding more closely associated with the motivational properties of incentive stimuli. However, although affective ratings were obtained prior to conditioning, behavioural measures of motivation were taken post-conditioning. Although habituation and sensitization effects cannot be ruled out, the variable schedule could not be administered prior to conditioning as the number of presentations of the outcome may not have been equal for participants and this may have caused confounds in the subsequent conditioning phase. Another improvement on the previous design in relation to emotional measurements, was to measure emotional conditioning throughout training, rather than to attempt to induce emotional conditioning separately at the beginning. This change was implemented for two reasons: firstly, some level of learning discrimination (between the CS+ and the CS-) had already occurred during the emotional conditioning phase according to the first expectancy ratings in the subsequent declarative conditioning phase in experiment 3.1. This created difficulties when trying to interpret the subsequent attentional data, as the absence of a decrease in attention to the CS+ during the declarative conditioning phase may have been due to this prior learning. Secondly, having emotional ratings within the explicit training phase may be a more accurate means of tracking the relationship between attention and emotion. Further measures were also introduced in order to clarify the relationship between incentive stimuli and attention. As discussed in the general introduction section, emotionality may be conceptualised as being composed of both valence and arousal dimensions, and according to some theories the arousal component of emotion has a stronger association with attention than the valence component. For example, Aquino & Arnell (2007) reported that ratings of arousal rather than valence, for positive and negative word stimuli, were related to interference in the performance of a concurrent digit-parity task. Similar findings were reported in a study by Schimmack & Derryberry (2005), where interference (as measured by increased reaction times in solving maths problems) was related to arousal ratings of positive and negative pictorial stimuli, but not to the valence ratings of such stimuli. Thus, in the present study, measures of arousal for the conditioned stimuli were included in order to provide an additional, and possibly separate, measure of incentive value. Skin conductance response was considered an appropriate measure of arousal to use in the current study as there is evidence that it reflects the arousal but not the valence component of affective stimuli. Gomez & Danuser (2004) reported that whilst listening to fragments of music, self-reported levels of arousal, but not self-reported valence ratings matched levels of skin conductance response. Likewise, Lang et al. (1993) reported similar findings but used visual images that varied along valence and arousal dimensions. They found that there was a significant covariation between skin conductance response and subjective arousal ratings, while no such covariation was reported between skin conductance and valence ratings. Finally, there is evidence that the skin conductance response is related to the motivational component of incentive stimuli as skin conductance responses were greater in the presence of a cannabis cue only for those who were frequent users of the drug (Wolfling, Flor, & Grusser, 2008), while levels of nicotine-deprivation were positively correlated with skin conductance responses to smoking cues, which in turn was related to self-reported desire to smoke (Payne, Smith, Sturges, & Holleran, 1996). Collectively, these findings provide substantial evidence that the skin conductance response reflects motivational activation, which is distinct from the valence of a stimulus. Thus, it was hypothesised that conditioned skin conductance responses would provide a distinct measure of incentive value to subjective emotional ratings. For the skin conductance measure, analysis followed that of another conditioning design: Delgado, Jou, Ledoux, & Phelps (2009) measured the base to peak amplitude in the first 4.5 seconds that the conditioned stimulus was present, prior to an instrumental response being made. Hence, in the present study arousal was measured as the base to peak amplitude during the presentation of the stimulus (3000ms) but prior to an expectancy response being made. This being the first time the skin conductance response was introduced into the investigation, another measure of arousal was included in order to validate it as a measure of arousal. Guntupalli, Everhart, Kalinowski, Nanjundeswaran, & Saltuklaroglu (2007) reported that increases in arousal for certain stimuli could be detected when measured via self-assessment mannikins or skin conductance responses, while Roedema & Simons (1999) reported that decreases in skin conductance for certain stimuli were matched by concurrent decreases in arousal as measured on a self-assessment mannikin. Consequently, arousal measured using a self-assessment mannikin should be a suitable measure for validating the physiological measure of arousal. However, both measures of arousal were obtained after the main conditioning session as it would have been difficult to gain pure baseline measures of skin conductance during the main conditioning session due to the short duration between trials. In order to achieve relatively pure baseline measures of skin conductance activity, additional conditioning trials will be introduced at the end of the conditioning session with two minute breaks incorporated between trials.

In addition to the measures designed to enhance the possibility that incentive mechanisms of attention would be detected, another improvement was incorporated to enhance the sensitivity of the design in detecting prediction error mechanisms of attention. The previous study employed a delay conditioning design (the CS was still present during the presentation of the unconditioned stimulus), but a prior investigation indicated that a trace conditioning design (a gap between the offset of the CS and the unconditioned stimulus) facilitated attention-mediated learning processes to a greater extent. Carter, Hofstotter, Tsuchiya, & Koch (2003), reported that increasing working memory load during conditioning interfered more with when the procedure was a trace design, than when it was a delay design, implying that attention may be a more important mediator of learning in trace conditioning designs. Thus, to increase the probability that learning-mediated mechanisms of attention would be detected, a delay between the CS and the outcome was introduced.

The predictions in the current design largely replicated those from the previous chapter. If attention was mediated by the uncertainty of the stimulus in accordance with the Pearce and Hall (1980) model, dwell time bias should be greatest for the partial predictor (CS+/-). Likewise, likelihood to first fixation measures may also be mediated by the uncertainty of the stimulus, such that as the outcome is learnt it is more likely to be attended to first in order to facilitate more efficient processing. In contrast, if attention is mediated by the incentive value of the stimuli as postulated by theories of appetitive (Robinson & Berridge, 1993; Stewart et al., 1984) and aversive (Van Damme, Crombez et al., 2004; Van Damme, Lorenz et al., 2004) attention, then dwell time bias should be in the order of magnitude CS+>CS+/->CS-. Attention should also be greater for stimuli associated with the higher incentive outcome relative to that of the lower incentive outcome. In addition, a further dissociation may become apparent between the two measures of attention – dwell time and likelihood of first fixation – as some models state that incentive value is important in the capture of attention only (Scherer, 2001), while others postulate a role for it in both the initial attraction and maintenance of attention (Lang et al., 1993). In addition to theories postulating that the incentive value of a stimulus attracts and/or holds attention, some theories concerning negatively-valenced stimuli argue for a different pattern of attention. Some of these theories suggest that an initial attentional bias to threatening stimuli will be subsequently followed by avoidance due to the negative affective properties of the stimulus (Mogg, Bradley et al., 2004).

Method

Subjects

64 (32 male) participants aged between 18 to 57 (SEM 22.00 ± 0.64) were recruited from the student population at the University of Sussex. All Participants had a minimum of 20:30 vision and gave informed written consent. None of them had hearing difficulties, or were currently taking anti-psychotic medication. Participants were randomly assigned to 1 of 4 conditions: high reward (50p), low reward(10p), high aversive(102db), or low aversive (97db). Within each condition participants were randomly assigned to one of four different counterbalance conditions. The University of Sussex ethics committee approved the study. Participants were paid a minimum of £5 and a maximum of £20 (dependent upon the condition) for their participation in the study.

Design

A 4 way mixed design was employed. The between-subject variables were valence (2: money, noise) and intensity level (2: high, low), and the within-subject variables were stimulus (3: CS+, CS+/-, CS-) and block (2: block 1, block 2).

Materials

Initial procedures

Questionnaires: As in experiment 3.1 a medical history questionnaire ensured that participants were in general good health and adhered to the exclusion criteria. The POMS (McNair, Lorr, & Doppleman, 1971) was used to measure participant's current anxiety and depression level, and a BIS and BAS questionnaire (Carver and White, 1994) assessed the strength of participants' level of activation of systems regarding reward and punishment.

Visual Acuity: As used in experiment 3.1, to ensure that participants would be able to discriminate between the visual stimuli they took the Snellen 3-m visual acuity test to make sure their eyesight was at a minimum level of 20:30.

Conditioning sessions

Conditioned stimuli: The same four stimuli were used for the conditioned stimuli as were used in the previous study.

Unconditioned stimuli: In the aversive conditions the outcome was either a 97db (low aversive condition) or 102b (high aversive condition) white noise lasting 40 milliseconds presented binaurally through headphones (Sennheiser PX200). In the reward conditions there were two tins on either side of the keyboard – the one on the right contained either 86 10ps (low reward condition) or 86 50ps (high reward condition). During the trials if participants were informed they had received money they would take the money out of the box on the right and move it into the box on the left.

Eye-tracking measures: Eye movements were tracked using an Eyelink II eye-tracker as used in experiment 3.1. Eye movements were measured throughout the whole of the conditioning trials.

Arousal conditioning trials

Galvanic skin conductance response: Galvanic skin response was measured using Skin Conductivity Measurement software version 1.0 for Windows 98 (written by Peter Reed, School of Biological Sciences, University of Sussex). A separate PC sampled skin conductance in micro siemens once per second through silver-silver chloride electrodes connected to the left index and ring finger. Med Associated Inc. (http://med-associates.com/index.htm) skin prep fluid (TD-260) and electrode paste (TD-246) were employed.

Visual analogues Scales: To measure subjective arousal an arousal self-assessment manikin was employed (M. M. Bradley & Lang, 1994). This is a 1-9 scale of arousal using pictorial stimuli to represent the different levels of the arousal. The scale can be found in Appendix 3.

Variable interval schedule materials

Visual stimuli: Visual stimuli were used to signal the beginning of the time period when a response could be made to obtain the reward outcome, or to avoid the noise outcome. These can be found in Appendix 3.

Procedure

The study lasted approximately an hour for each participant. After the participants filled in the questionnaires described in the materials section, and gave their written informed consent they were given the Snellen 3-m visual acuity test. All participants were then seated at a table in front of desktop PC, and the eye tracker device and headphones were attached to their head. Eye movement was then calibrated by the experimenter using the Eyelink II program. After providing an affective rating of the outcome, there then followed 144 trials of discriminative training for the different stimulus contingencies. After these set of trials, electrodes were attached to the index and ring finger and two more of each of the 3 trial types from the discriminative training were presented in random order. The electrodes were removed and participants provided subjective arousal ratings for the visual stimuli, and finally completed a VI schedule comprising of ten intervals, for the outcome they had experienced during training. Participants were then debriefed as to the purpose of the experiment and received appropriate monetary payment. The experimenter was present for all stages of the procedure.

Initial procedures

After participants' visual acuity was tested, they completed questionnaires and the consent form.

Outcome incentive value

Before the discriminative training began, participants were presented with the outcome according to the condition they were in and had to provide a rating according to how much they liked (money) or disliked (noise) the outcome. In the case of the noise they were simply presented with the noise through the headphones, but with the money the participants received 10p or 50p before being asked to rate how much they liked receiving it. Ratings were provided using a 9-point Likert scale.

Conditioning procedure

During conditioning trials pairs of visual stimuli were presented on the screen. The four visual stimuli described in the materials section predicted differing probabilities of the outcome occurring. When stimulus A was on the screen it predicted that the outcome would occur 100% of the time (CS+), when stimulus B was on the screen it predicted that the outcome would occur 50% of the time (CS+/-), and when the C stimulus appeared on the screen it predicted that the outcome would occur 0% of the time (CS-). X was a control stimulus and appeared as part of a stimulus pair in conjunction with A, B, or C. Order of presentation on which side of the screen the stimulus appeared in the pair was also counterbalanced giving a total of 6 stimulus pairs. These 6 pairs were presented six times per block giving a total of 36 trials per block. There were 4 blocks of training in total. Order of presentation in each block was randomised within a block of 12 that was repeated 3 times in order to minimise the number of consecutive presentations of the same stimulus pairs.

Conditioning trial procedure

Each trial proceeded in the following way: a fixation cross appeared in the centre of the screen and once the pupil was fixated on the centre of the cross the experimenter pressed the space bar on a separate computer and the cross disappeared to be replaced by a stimulus pair. This pair remained on the screen for 3 seconds then disappeared. Participants were then asked to rate how likely they thought the outcome would occur using a 9-point Likert scale. Once they had responded there was a blank screen for 1.5 seconds, followed by the appropriate outcome for that trial. For the noise conditions there was either a 40ms noise or 40ms silence. For the money conditions this was either presentation of the words *"You have received 10p (or 50p)"* on the screen for 2 seconds or no text for 2 seconds. For the noise condition the outcome was followed by an inter-trial interval (ITI) of 3.6 seconds of blank screen, while for the money conditions this was 2 seconds. After every 36 trials each individual stimulus was presented in the centre of the screen with a question asking either how anxious or how pleasant they found the stimulus. Responses were made using a 9-point Likert scale. The order of presentation of these questions with each stimulus was randomized.

Arousal conditioning trials

Before the trials began baseline GSR readings were taken while participants watched a blank screen for 2 minutes. The trials then proceeded as in the discriminative training sessions but there was an additional minute of blank screen in-between trials. The only differences during the trials in this part of the procedure were that when making a response during the expectancy question there was a fixed time period of 5 seconds in which to respond, and the fixation cross that appeared was up for a fixed 2 second period. There were two presentations of each trial type; one with the predictive stimulus on the left, the other with it presented on the right. For the CS+/-, one presentation was followed by the outcome while the other wasn't. The side of the screen the CS+/- was on when it was followed by the outcome was counterbalanced between participants within each condition. Order of presentation of these trials was also randomized. The electrodes were then removed and participants rated their level of arousal for each of the stimuli using a visual analogue scale.

Variable-interval schedule

Participants were presented with a new stimulus that predicted the outcome (see Appendix 3). There was one presentation trial where the new stimulus was paired with the outcome. They were then instructed that when the picture subsequently appeared on the screen they would have to press the spacebar many time in order to avoid/receive the outcome. For each VI trial the stimulus appeared for a total of 4 seconds. There was a 1 second time window, which could occur at any time point within this 4 seconds, and one spacebar press had to fall within this time window in order to receive the reward or avoid the noise. At the end of the 4 second stimulus presentation, if they pressed during the time window they received the money or received written feedback that they had avoided the noise. Failure to press the spacebar during the time window resulted in written feedback that they had not received the money, or a blast of noise. There were ten intervals in total.

Statistical analysis

Corrections were made for all of the dependent variables such that any value 3 standard deviations above the mean was replaced with the mean of the level it was entered for analysis. Assumptions of all statistical procedures applied were checked. In the case of violation of the assumption of homogeneity of variances, the Greenhouse-Geisser adjustment was applied and adjusted degrees of freedom are reported. For significant main effects, post-hoc analyses with Bonferroni-corrected t-tests were used. All results were significant at $p<0.05$ unless otherwise stated. All analyses were performed using the Statistical Package of Social Sciences (SPSS 16).

Exclusion criteria:

Participants were excluded from the subsequent analysis if they failed to have statistically significantly discriminated between the CS+ and CS- by the end of Pavlovian training (final 36 trials), according to mean expectancy ratings.

Questionnaires:

To make sure that the groups were balanced in terms of age, BIS, BAS, anxiety and depression one-way ANOVAs were performed on all of these variables.

Evaluation of outcome incentive value:

Subjective affective ratings: To check that there was a difference between high and low intensities of the same reinforcer, t-tests were performed between unpleasantness ratings for 97db and 102db, and between pleasantness ratings for 10p and 50p.

Instrumental responding: behavioural measures of incentive value were calculated as the mean number of times they pressed the spacebar over the ten intervals. This value was then analysed using a 2-way between-subjects ANOVAs with intensity of outcome (3 levels: low, medium, high) and valence of outcome (2 levels: money, noise) as the between-subject factors.

Variables measuring attention during conditioning:

Dwell time bias: the total looking time (dwell time) for each stimulus on every trial was recorded and log transformed. Dwell time bias was calculated by subtracting the dwell time for the context stimulus X from the dwell time for the predictive stimulus (A, B, or C).

Likelihood to first fixation: Likelihood of first fixation scores were first converted into ratios (see experiment 3.1).

Scores for both measures were subsequently collapsed into two blocks per stimulus for analysis, and were analysed using 3-way ANOVAs with valence (2 levels: money, noise) and intensity (2 levels: low, high) as the between-subjects variables, and predictive value as the within-subjects variable (3 levels: CS+, CS+/-. CS-).

Variables measuring learning during conditioning:

Expectancy ratings: Expectancy ratings were collapsed into two blocks, and were subsequently analysed using a 3-way ANOVA with valence (2 levels: money, noise) and intensity (2 levels: low, high) as the between-subjects variables, and predictive value as the within-subjects variable (3 levels: CS+, CS+/-. CS-).

Variables measuring emotional responses during conditioning:

Conditioned emotional ratings: Pleasantness ratings for the money conditions and anxiety ratings for the noise conditions were both collapsed into two blocks per stimulus before being analysed with 2-way ANOVAs with intensity (2 levels: low, high) as the between-subject variable, and predictive value as the within-subjects variable (3 levels: CS+, CS+/-, CS-).

Variables measuring conditioned arousal:

Galvanic skin conductance response: the amplitude of the response for each trial was measured as the highest amplitude from stimulus onset until the end of the stimulus presentation during that trial (3000ms). The baseline amplitude for each trial was the amplitude in the final 1 second time period of the 2 minute ITI measured just prior to the beginning of that trial. For each trial baseline amplitudes were subtracted from the maximal amplitude and were measured in microseimens (µs).

Subjective arousal ratings: an arousal rating was obtained for each of the conditioned stimuli.

GSR and subjective arousal were analysed using 3-way ANOVAs with valence (2 levels: money, noise) and intensity (2 levels: low, high) as the between-subjects variables, and predictive value as the within-subjects variable (3 levels: CS+, CS+/-. CS-).

Other analyses:

<u>Relationship between emotion and attention:</u> The relationship between emotion and attention was further investigated by analysing Pearson's correlation coefficients for the mean dwell time bias of the CS+ and the mean emotional ratings for the CS+ for all conditions. For the noise conditions the mean anxiety ratings were used, while for the money conditions the mean pleasantness ratings were used.

Results

Exclusion criteria:

The following subjects were excluded from the analysis as they didn't match the contingency-awareness criteria: 3 subjects from the 97db condition, 5 subjects from the 10p condition, and 4 subjects from the 50p condition. No subjects were excluded from the 102db condition. Table 4.1.2 shows the number and gender of participants in each condition after the exclusion criteria was applied. Data for the unaware participants can be found in Appendix 3.

Questionnaires:

There were no differences between conditions in any of the variables reported in Table 4.1.1 ($Fs(4) < 1.10$, $p > 0.35$).

Table 4.1.1: Variables related to mood and appetitive and aversive motivation, shown separately for each condition. Values are mean ± SEM (range in brackets)

	97db	102db	10p	50p
Age (years)	20.62 ± 0.94 (18-31)	22.94 ± 1.66 (18-41)	24.18 ± 3.40 (18-57)	23.08 ± 1.20 (19-32)
BIS	2.92 ± 0.11 (2.29-3.57)	2.95 ± 0.09 (2.43-3.71)	3.23 ± 0.16 (2.43-4.00)	3.02 ± 0.13 (2.43-3.86)
BAS	2.95 ± 0.12 (2.12-3.58)	2.93 ± 0.11 (2.02-3.92)	2.98 ± 0.12 (2.18-3.60)	3.00 ± 0.11 (2.42-3.67)
Anxiety	0.23 ± 0.19) (-0.33-2.22)	0.38 ± 0.17 (-0.33-1.89)	0.36 ± 0.23) (-0.44-2.22)	0.19 ± 0.13 (-0.44-0.78)
Depression	0.34 ± 0.17 (0.00-2.20)	0.42 ± 0.11 (0.00-1.27)	0.33 ± 0.07 (0.00-0.67)	0.37 ± 0.13 (0.00-1.33)

Table 4.1.2: The number of males and females in each condition after the exclusion criteria was applied

97db	102db	10p	50p
5 female, 8 male	8 female, 8 male	5 female, 6 male	6 female, 6 male

Evaluation of outcome incentive value:

Subjective affective ratings: There were no differences between noise outcomes or between money outcomes ($t<1.60$, $p>0.11$). The mean affective ratings for each stimulus are presented in table 4.1.3.

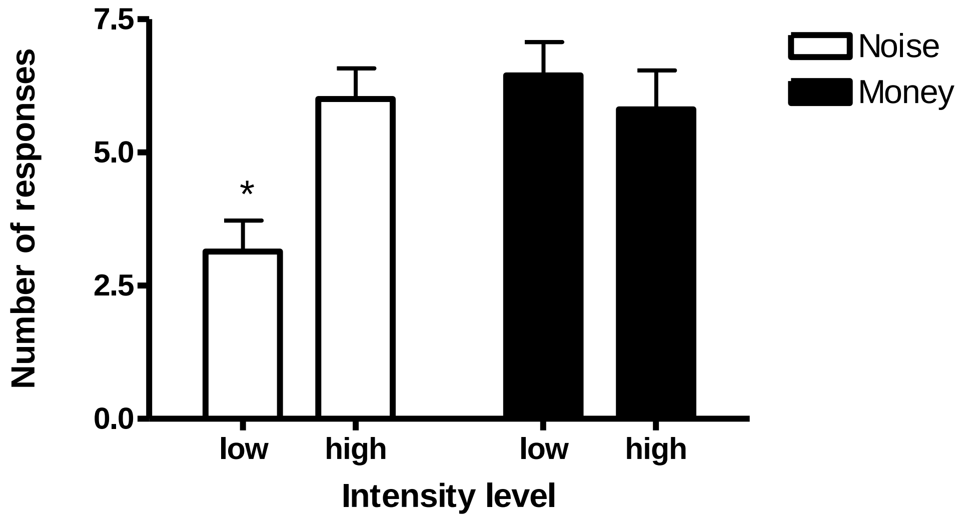
Table 4.1.3: Affective values of the outcome measured on a 1-9 Likert scale, obtained prior to conditioning. Scales used were different for noise and money outcomes. Values are mean ± SEM

97db	102db	10p	50p
3.44 ± 0.21	2.92 ± 0.24	8.19 ± 0.29	8.50 ± 0.23

Instrumental responding: There was a main effect of valence ($F(1,48) = 7.03$, $p<0.05$), where the overall mean number of responses was greater across the money conditions (6.12 ± 0.48) compared to the noise conditions (4.51 ± 0.50). There was also a borderline effect of level ($F(1,48) = 3.76$, $p=0.06$), indicating a trend towards a greater number of responses in the high level conditions (5.92 ± 0.45) compared to the low level conditions (4.47 ± 0.55).

Figure 4.1.1 shows the valence x level interaction ($F(1,48) = 8.65$, $p<0.05$), which indicates that while the number of responses made was greater in the 102db condition relative to the 97db condition ($t(27) = 3.75$, $p<0.05$), there was no difference in the number of responses made between the 10p and 50p conditions ($t(21) = 0.66$, $p=0.52$).

Figure 4.1.1: The number of responses made during a period of 10 intervals on a variable interval schedule in order to avoid a noise (97db or 102db) or to receive a reward (10p or 50p). Values are mean ± SEM



* = p<0.05 compared to the high intensity noise

Variables measuring attention during conditioning:

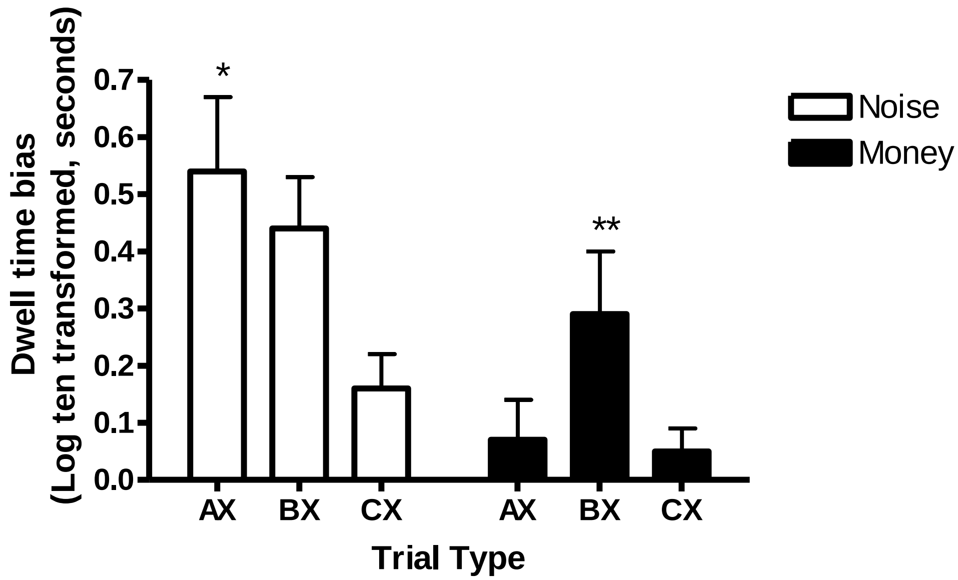
Dwell time bias: There was a main effect of block ($F(1,48) = 4.29$, $p<0.05$), where there appeared to be a general increase in dwell times from block 1 (0.21 ± 0.05) to block 2 (0.33 ± 0.07). A main effect of valence ($F(1,48) = 5.29$, $p<0.05$) indicated that overall dwell times were greater for the noise outcomes (0.38 ± 0.08) compared to the money outcomes (0.14 ± 0.07). A valence x level ($F(1,48) = 6.94$, $p<0.05$) interaction indicated a non-significant difference between overall means in the two noise conditions ($t(27) = 0.95$, $p=0.35$), and a significant difference between overall means between the two money conditions ($t(21) = 3.45$, $p<0.05$). However, this was not investigated further.

There was a main effect of stimulus ($F(2,96) = 7.69$, $p<0.05$), indicating that while there was no significant difference in dwell time bias between A (SEM 0.33 ± 0.08) and B (SEM

0.32 ± 0.06) ($F(1,48) = 0.87$, $p=0.36$) dwell time for A was significantly greater than for C (SEM 0.11 ± 0.04) ($F(1,48) = 7.83$, $p<0.05$).

Figure 4.1.2 shows a stimulus x valence interaction ($F(2,96) = 3.84$, $p<0.05$), which indicates that there was a significant interaction between valences in the relationship between A and B ($F(1,48) = 4.01$, $p=0.05$) and between A and C ($F(1,48) = 6.64$, $p<0.05$). These interactions were further explored by breaking down the two way interaction by valence. In the collapsed noise conditions there was a main effect of stimulus ($F(1.60, 44.68) = 7.12$, $p<0.05$) where planned contrasts showed that the difference between A and B was not significant ($F(1,28) = 0.62$, $p=0.44$) while A and C was significant ($F(1,28) = 11.51$, $p<0.05$). In the collapsed money conditions there was a main effect of stimulus ($F(1.49, 32.83) = 5.20$, $p<0.05$) where planned contrasts showed that there was a significant difference between A and B ($F(1,22) = 7.21$, $p<0.05$), while there was no difference between A and C ($F(1,22) = 0.06$, $p=0.82$). Post-hoc t-tests revealed that there was no significant bias for A ($t(22) = 0.95$, $p=0.36$) or for C ($t(22) = 1.20$, $p=0.25$), while B was significant from zero ($t(22) = 2.50$, $p<0.05$).

Figure 4.1.2: Dwell time bias values calculated as context dwell time (X) subtracted from the predictive stimulus dwell time (A, B or C), during conditioning, collapsed across all trials. The two noise outcomes (97db and 102db) and the two money outcomes (50p and 10p) were collapsed. Values are mean ± SEM

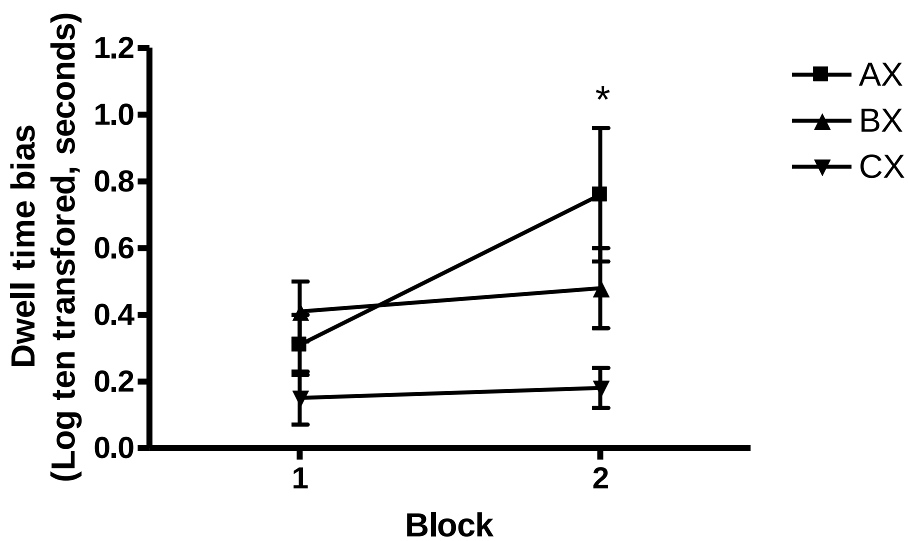


* = p<0.05 compared to CX

** = p<0.05 compared to AX and CX

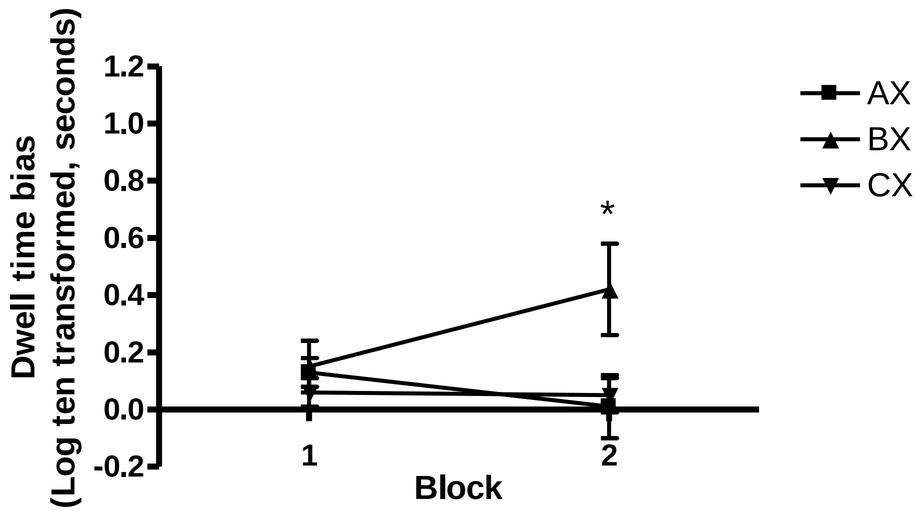
A stimulus x block x valence interaction (F(2,96) = 5.71, p<0.05) indicated that there was an interaction between valences in the relationship between A and B across blocks (F(1,48) = 11.88, p<0.05), and between A and C across blocks (F(1,48) = 3.98, p=0.05). These interactions were further investigated through breaking down the 3-way interaction into two 2-way interactions. Figure 4.1.3 shows that in the noise conditions there was a stimulus x block interaction (F(2,56) = 3.58, p<0.05) where planned contrasts showed a significant difference between A and B over blocks (F(1,28) = 5.45, p<0.05) and A and C over blocks (F(1,28) = 4.25, p<0.05). Subsequent post-hoc t-tests showed that dwell time bias for A increased significantly across blocks (t(28) = 2.96, p<0.05) while neither B nor C significantly increased across blocks (t<1.87, p>0.06). Figure 4.1.4 shows that in the money conditions there was also a stimulus x block interaction (F(2,44) = 4.18, p<0.05) where planned contrasts revealed a significant difference between A and B over blocks (F(1,22) = 7.87, p<0.05), but not between A and C over blocks (F(1,22) = 0.75, p=0.40). Subsequent post-hoc t-tests revealed that while A did not significantly decrease over blocks (t(22) = 0.54, p=0.60), B significantly increased over blocks (t(22) = 2.14, p<0.05). C also did not significantly decrease over blocks (t(22) = 1.01, p=0.33).

Figure 4.1.3: Dwell time bias values during conditioning on AX, BX, and CX trials, presented as two separate blocks, collapsed across 97db and 102db conditions. Values are mean ± SEM



* = p<0.05 for AX in block 2 compared to AX in block 1

Figure 4.1.4: Dwell time bias values during conditioning on AX, BX, and CX trials, presented as two separate blocks, collapsed across 10p and 50p conditions. Values are mean ± SEM



* = $p<0.05$ for BX in block 2 compared to BX in block 1

Although there were no stimulus x valence x level interactions, Table 4.1.4 shows the mean dwell time values for each stimulus per condition. The mean values for the 97db condition indicate a greater bias for the B than for the A, while mean values in the 102db condition appear to indicate that dwell time biases were greater for the A over the over the B stimulus. In contrast both the 10p and the 50p appeared to follow a similar pattern of dwell time biases.

Table 4.1.4: Dwell time bias values on AX, BX, and CX trials during conditioning, collapsed across trials, presented separately for each condition. Values are mean ± SEM

	AX (logten,seconds)	BX (logten,seconds)	CX (logten,seconds)
97db	0.37 ± 0.11	0.40 ± 0.06	0.11 ± 0.09
102db	0.67 ± 0.21	0.47 ± 0.14	0.21 ± 0.08
10p	0.23 ± 0.08	0.39 ± 0.12	0.18 ± 0.05
50p	-0.07 ± 0.04	-0.02 ± 0.07	-0.10 ± 0.06

Likelihood to first fixation: There was a main effect of valence only ($F(1,48) = 6.75$, $p<0.05$), which indicated that the predictive stimuli in the noise condition were most likely to be fixated to first (SEM 0.14 ± 0.03) compared to predictive stimuli in the money condition (SEM 0.04 ± 0.03). Although there were no other effects mean ratio values for each stimuli are presented in table 4.1.5.

Table 4.1.5: Likelihood ratios of the predictive stimulus being fixated to first (A, B, or C) on AX, BX and CX trials during conditioning, collapsed across trials, presented separately for each condition. Values are mean ± SEM

	AX	BX	CX
97db	0.13 ± 0.02	0.11 ± 0.03	0.11 ± 0.07
102db	0.16 ± 0.06	0.16 ± 0.05	0.14 ± 0.06
10p	0.12 ± 0.06	0.09 ± 0.04	0.03 ± 0.05
50p	0.00 ± 0.02	0.05 ± 0.03	-0.06 ± 0.02

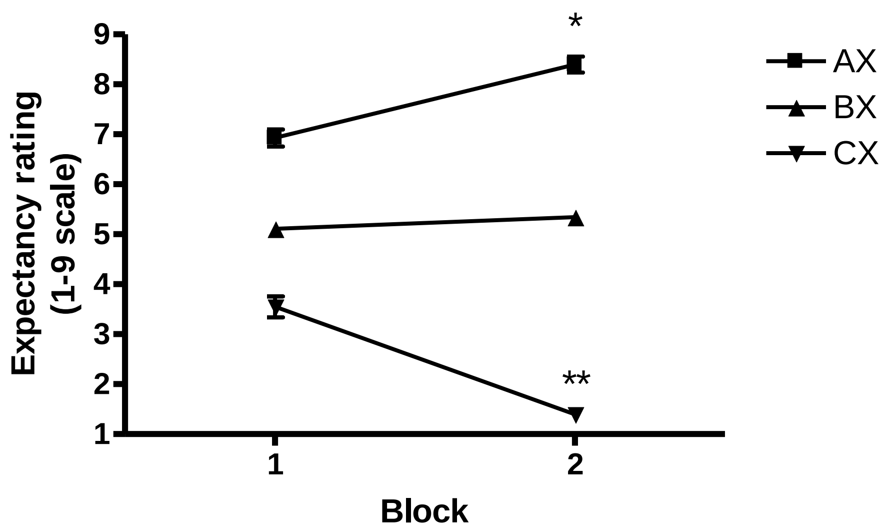
Variables measuring learning during conditioning:

Expectancy ratings: There was a main effect of block ($F(1,48) = 5.77$, $p<0.05$) where overall expectancies decreased from block 1 (SEM 5.20 ± 0.07) to block 2 (SEM 5.05 ± 0.06). A main effect of valence ($F(1,48) = 5.39$, $p<0.05$) also indicated that overall expectancies were greatest in the noise conditions (SEM 5.23 ± 0.05) compared to the money conditions (SEM 4.98 ± 0.10).

The main effect of stimulus ($F(1.60, 76.74) = 356.39$, $p<0.05$) was in the predicted direction where A expectancy (SEM 7.67 ± 0.14) was greater than B expectancy (SEM 6.23 ± 0.09) ($F(1,48) = 182.44$, $p<0.05$), and C expectancy (SEM 2.47 ± 0.13) ($F(1,48) = 478.54$, $p<0.05$).

Figure 4.1.5 shows the stimulus x block interaction ($F(2,96) = 124.21$, $p<0.05$), which also supported predictions that learning would increase over block. Planned contrasts indicated that the progression of learning differed between A and B ($F(1,48) = 34.86$, $p<0.05$), and between A and C ($F(1,48) = 193.89$, $p<0.05$). Additional post-hoc t-tests revealed that there was a significant increase in expectancy for A over block ($t(51) = 9.73$, $p<0.05$), no significant change for B ($t(51) = 1.80$, $p=0.08$)), while expectancy for C decreased over block ($t(51) = 12.09$, $p<0.05$). A further post-hoc paired-samples t-test to ascertain if learning had occurred in the first block indicated that there was a significant difference in block 1 between A and C ($t(51) = 10.79$, $p<0.05$).

Figure 4.1.5: Expectancy ratings on AX, BX, and CX trials, presented as two separate blocks during conditioning, collapsed across all money and noise conditions. Values are mean ± SEM

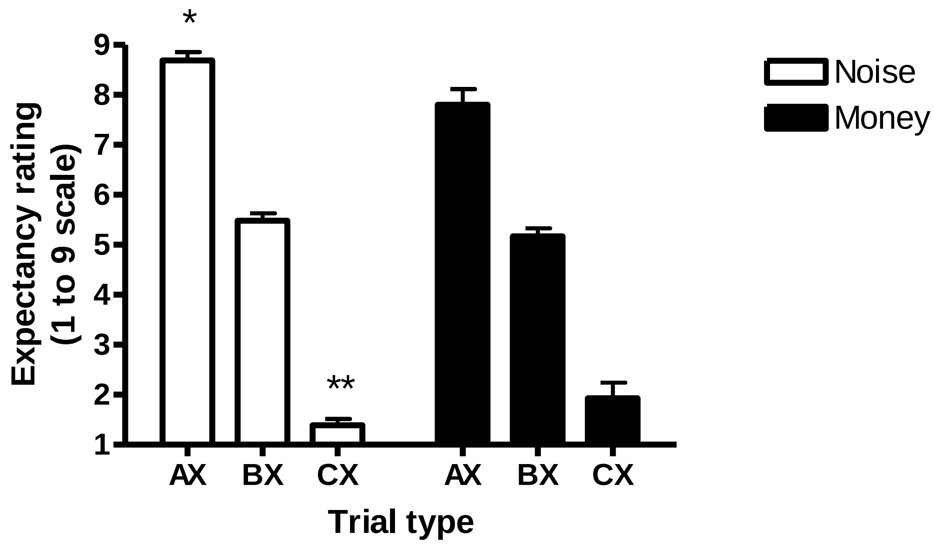


* = p<0.05 AX in block 1 compared to AX in block 2

** = p<0.05 CX in block 1 compared to CX in block 2

There was also a stimulus x block x valence ($F(2,96) = 7.72$, $p<0.05$). However, no planned contrasts were performed as no specific predictions were made regarding interaction effects. Post-hoc between-subjects t-tests were conducted on expectancy ratings during AX and CX trials in the final block of learning in order to ascertain whether there were differences in learning between noise and money conditions at the end of training. Figure 4.1.6 shows the post-hoc analysis on the final block of learning between conditions, and indicates that expectancy for AX trials was greater in the noise conditions than the money conditions ($t(50) = 3.71$, $p<0.05$) and expectancy ratings were lower for CX trials in the noise conditions compared to the money conditions ($t(50) = 2.08$, $p<0.05$).

Figure 4.1.6: Expectancy ratings on AX, BX, and CX trials during conditioning, collapsed across trials, and presented separately for combined noise conditions (97db and 102db) and combined money conditions (10p and 50p). Values are mean ± SEM



* = p<0.05 compared to money AX

** = p<0.05 compared to money CX

Table 4.1.6 shows the mean expectancy ratings during each trial type per condition. Mean values indicated that the higher intensity outcomes elicited a slightly greater expectancy discrimination.

Table 4.1.6: Expectancy ratings during AX, BX, and CX trials, collapsed across conditioning trials, presented separately for each condition. Values are mean ± SEM

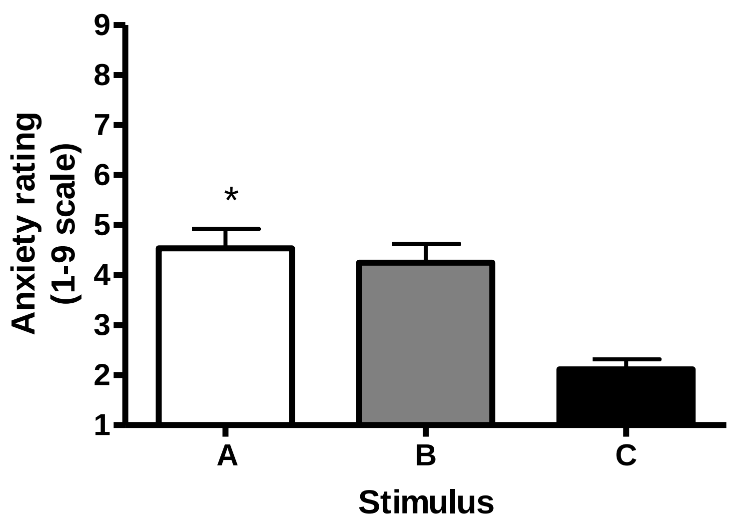
	AX	BX	CX
97db	7.73 ± 0.15	5.46 ± 0.15	2.56 ± 0.22
102db	8.03 ± 0.14	5.25 ± 0.19	2.37 ± 0.19
10p	7.07 ± 0.53	5.07 ± 0.20	2.90 ± 0.38
102db	7.66 ± 0.27	5.09 ± 0.17	2.12 ± 0.27

Variables measuring emotional conditioning:

Anxiety (noise conditions only): There was a block x level interaction (F(1,27) = 10.00, p<0.05), indicating that overall anxiety ratings increased between block 1 (SEM 3.16 ± 0.23) and block 2 (SEM 3.84 ± 0.32) in the 97db condition (t(12) = 2.85, p<0.05), while for the 102db condition there was no difference in overall anxiety ratings between block 1 (SEM 3.92 ± 0.39) and block 2 (SEM 3.57 ± 0.38) (t(15) = 1.56, p=0.13).

Figure 4.1.7 shows a main effect of stimulus (F(2,54) = 19.27, p<0.05), revealing that in combined noise conditions there was no significant difference between A and B (F(1,27) = 0.47, p=0.50), while there was between A and C (F(1,27) = 31.26, p<0.05).

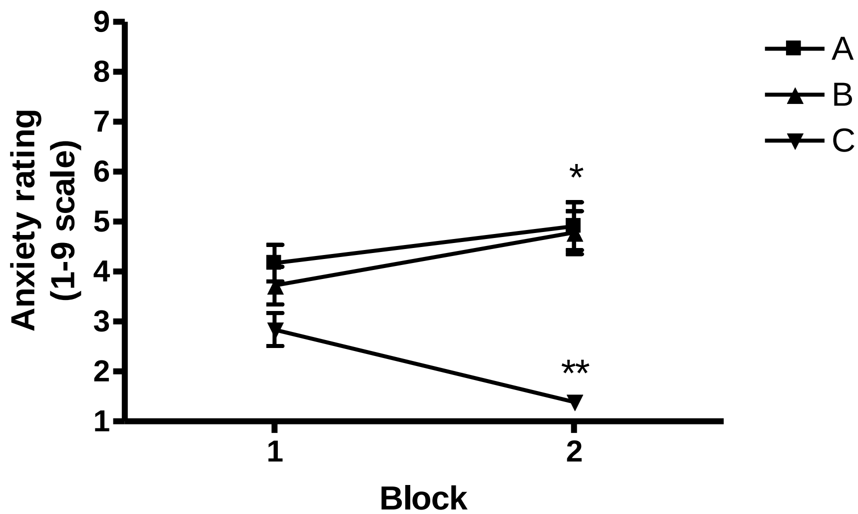
Figure 4.1.7: Anxiety ratings for stimuli A, B and C during conditioning, collapsed over trials for combined noise conditions (97db and 102db). Values are mean ± SEM



* = p<0.05 compare to stimulus C

Figure 4.1.8 shows a stimulus x block interaction (F(2,54) = 15.36, p<0.05), indicating that anxiety for A and B progressed in a similar manner over block (F(1,27) = 0.30, p=0.59), while there was a significant difference between the progression of anxiety for A and C over block F(1,27) = 16.19, p<0.05). Additional t-tests showed that there was a significant increase in anxiety over blocks for both A(t(28) = 2.07, p<0.05), and B (t(28) = 3.31, p<0.05), while anxiety for C decreased over block (t(28) = 4.51, p<0.05).

Figure 4.1.8: Anxiety ratings for A, B, and C stimuli measured during conditioning, presented as two blocks of trials for combined noise conditions (97db and 102db). Values are mean ± SEM



* = p<0.05 for A and B stimuli compared between blocks

** = p<0.05 for C in block 1 compared to C in block 2

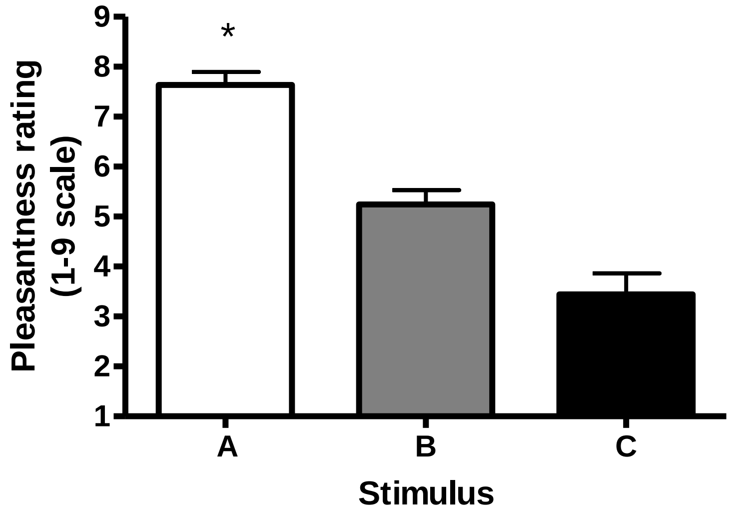
The data in table 4.1.7 indicates that anxiety ratings for A and B stimuli were greater in the 102db condition compared to the 97db condition, although this was not a significant effect.

Table 4.1.7: Anxiety ratings for A, B and C stimuli measured during conditioning, collapsed over trials, presented separately for 97db and 102db conditions. Values are mean ± SEM

	A	B	C
97db	4.34 ± 0.33	3.94 ± 0.37	2.23 ± 0.32
102db	4.47 ± 0.66	4.50 ± 0.61	2.02 ± 0.27

Pleasantness ratings (money only): Figure 4.1.9 shows a main effect of stimulus ($F(2,42) = 42.38$, $p<0.05$) indicating that in combined money conditions, as predicted, pleasantness ratings for A were greater than for B ($F(1,21) = 52.10$, $p<0.05$), and also for C ($F(1,21) = 63.21$, $p<0.05$).

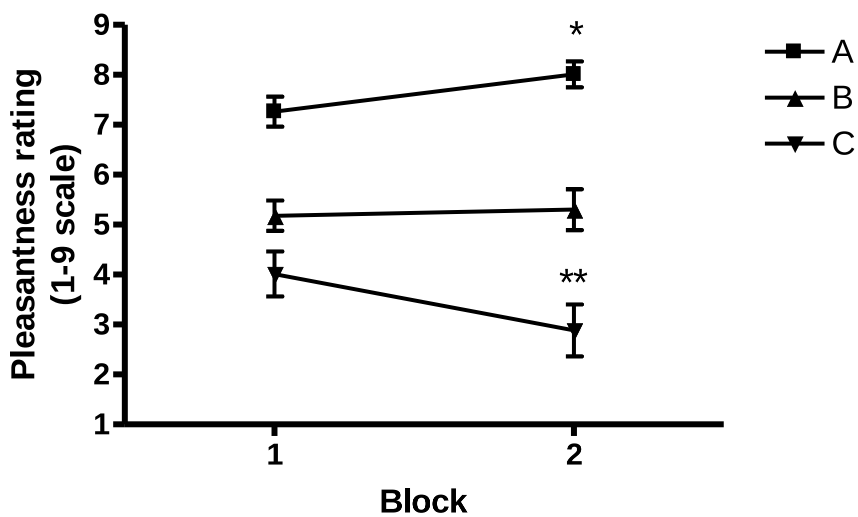
Figure 4.1.9: Pleasantness ratings for A, B and C stimuli measured during conditioning, collapsed over trials for combined 10p and 50p conditions. Values are mean ± SEM



* = p<0.05 compared to both B and C

Figure 4.1.10 shows a stimulus x block interaction (F(2,42) = 5.44, p<0.05) indicating that there was a significant difference in the development of pleasantness ratings between A and C (F(1,21) = 11.07, p<0.05), but not between A and B (F(1,21) = 1.68, p=0.21). Additional t-tests revealed that A pleasantness increased over block (t(22) = 3.23, p<0.05) while ratings for C decreased over block (t(22) = 2.83, p<0.05). Pleasantness ratings for B did not significantly change over block (t(22) = 0.30, p=0.77).

Figure 4.1.10: Pleasantness ratings for A, B, and C stimuli measured during conditioning, presented as two blocks of trials for combined 10p and 50p conditions. Values are mean ± SEM



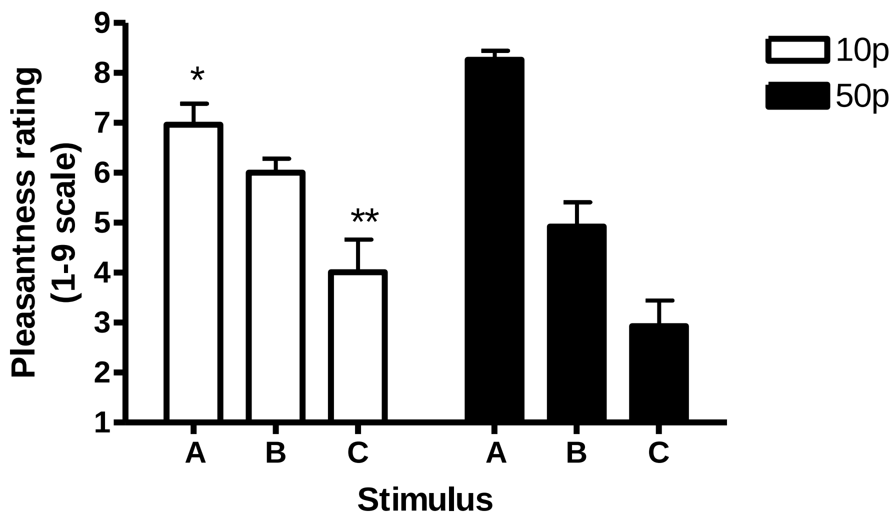
* = p<0.05 for A in block 1 compared to A in block 2

** = p<0.05 for C in block 1 compared to C in block 2

Figure 4.1.11 shows a stimulus x level interaction (F(2,42) = 4.00, p<0.05), revealing that there was a difference between conditions in the relationship between A and B (F(1,21) = 9.23, p<0.05) and between A and C (F(1,21) = 5.25, p<0.05). Post-hoc analysis revealed that A was rated as more pleasant in the 50p condition relative to the 10p condition (t(21) =

2.91, $p<0.05$) while there was no significant difference between groups in pleasantness ratings for B or for C ($t<1.34$, $p>0.19$).

Figure 4.1.11: Pleasantness ratings for A, B, and C stimuli measured during conditioning, collapsed over trial, and presented separately for 10p and 50p conditions. Values are mean ± SEM



* = $p<0.05$ compared to A in the 50p condition

** = $p<0.05$ compared to C in the 50p condition

Post-hoc tests on anxiety for B in the money conditions revealed that there was no significant difference in anxiety for B over block ($t(22) = 1.63$, $p=0.12$).

Variables measuring conditioned arousal:

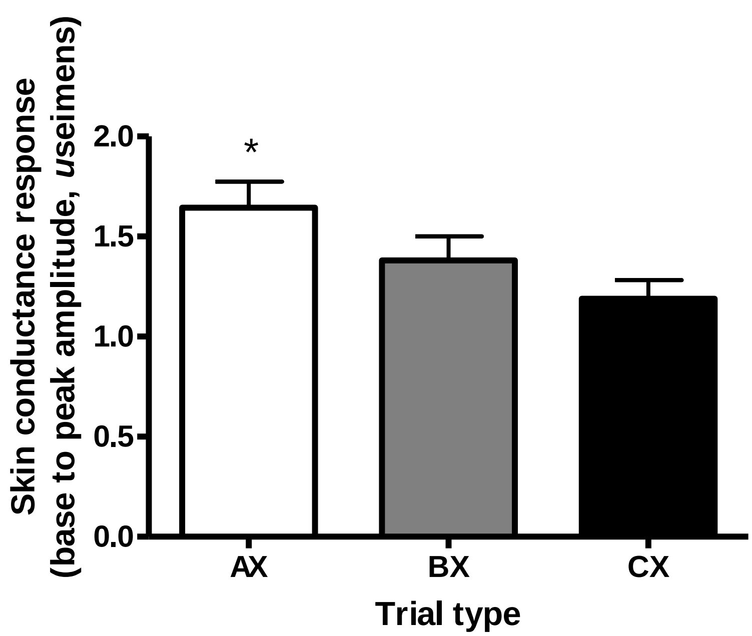
Galvanic skin conductance response:

Three subjects were excluded from the analysis due to technical problems.

There was a main effect of level ($F(1,45) = 5.66$, $p<0.05$) indicating that overall arousal levels were lower in the 10p and 97db groups (SEM 1.18 ± 0.12) compared to the overall arousal levels in the 102db and 50p groups (SEM 1.53 ± 0.09).

Figure 4.1.12 shows a main effect of stimulus ($F(2,90) = 6.77$, $p<0.05$), also indicating that arousal was greater for the A stimulus over both the B stimulus ($F(1,45) = 4.98$, $p<0.05$) and the C stimulus ($F(1,45) = 12.01$, $p<0.05$). Table 4.1.8 shows that there was a trend towards greater arousal for A stimuli in the higher intensity groups (50p and 102db) relative to the lower intensity groups (10p and 97db).

Figure 4.1.12: GSR base-to-peak amplitudes for A, B, and C stimuli measured during an additional conditioning phase, collapsed over trials, for all combined conditions (97db, 102db, 10p, 50p). Values are mean ± SEM



* = $p<0.05$ compared to BX and CX

Table 4.1.8: GSR base-to-peak amplitudes on AX, BX, and CX trials measured during an additional conditioning phase, collapsed over trials, presented separately for each condition (97db, 102db, 10p, 50p). Values are mean ± SEM

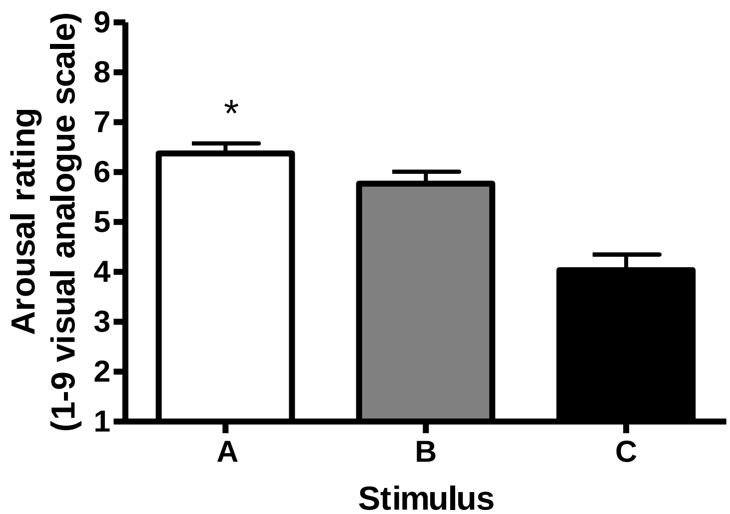
	AX	BX	CX
97db	1.34 ± 0.27	1.17 ± 0.24	1.10 ± 0.15
102db	1.71 ± 0.24	1.68 ± 0.28	1.05 ± 0.11
10p	1.60 ± 0.35	0.96 ± 0.18	0.91 ± 0.19
50p	1.70 ± 0.09	1.47 ± 0.12	1.60 ± 0.22

Subjective arousal ratings: There was a main effect of valence ($F(1,48) = 9.62$, $p<0.05$) where the overall arousal ratings were higher in the money condition (SEM 5.88 ± 0.27) compared to the noise condition (SEM 5.01 ± 0.15) and a main effect of level ($F(1,48) = 4.80$, $p<0.05$) where the overall arousal ratings were higher in the high intensity conditions (SEM 5.62 ± 0.28) compared to the low intensity conditions (SEM 5.13 ± 0.21). A valence x level interaction ($F(1,48) = 5.92$, $p<0.05$) indicated that there was no difference in overall arousal level between 102db (SEM 1.47 ± 0.14) and 97db (SEM 1.20 ± 0.19) noise conditions ($t(27) = 0.22$, $p=0.83$), while there was between high (50p) and low (10p) money conditions ($t(21) = 2.63$, $p<0.05$) where 10p (SEM 5.23 ± 1.34) yielded lower arousal ratings than 50p (SEM 6.48 ± 0.93).

Figure 4.1.13 shows a main effect of stimulus ($F(1.76, 85.24) = 23.09$, $p<0.05$,) indicating that the difference between A and B self-reported arousal did not quite reach significance

(F(1,48) = 3.75, p<0.06), but that self-reported arousal was significantly greater for A compared to C (F(1,48) = 35.08, p<0.05).

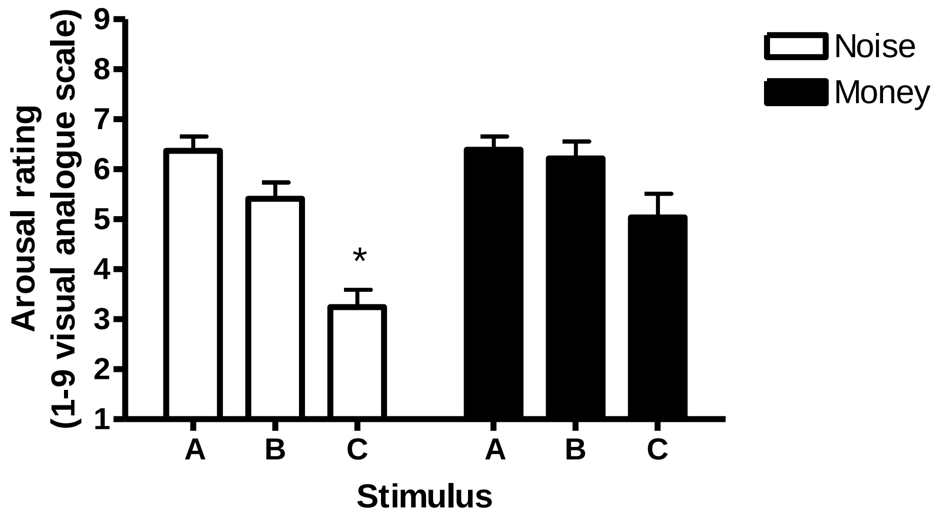
Figure 4.1.13: Self-reported arousal ratings for stimuli A, B, and C, measured using a visual analogue scale, after conditioning trials and combined over all conditions (97db, 102db, 10p, 50p). Values are mean ± SEM



* = p<0.05 compared to C

In addition, Figure 4.1.14 shows a stimulus x valence interaction (F(1.76, 85.24) = 3.43, p<0.05), revealing that there was no significant difference between valences in the relationship between A and B (F(1,48) = 1.83, p=0.18), but that there was a difference between valences in the relationship between A and C (F(1,48) = 5.63, p<0.05). Furthermore, post-hoc investigations revealed that while self-reported arousal for A was equal between valences (t(50) = 0.04, p=0.97), arousal for C was greater in the money conditions compared to the noise condition (t(50) = 3.13, p<0.05).

Figure 4.1.14: Self-reported arousal ratings for stimuli A, B, and C, measured using a visual analogue scale, after conditioning trials and combined for noise conditions (97db, 102db) and money conditions (10p, 50p). Values are mean ± SEM



* = p<0.05 compared to the money C

Other analyses:

Relationship between emotion and attention: For the noise conditions there was no significant correlation between anxiety and dwell time bias for A in the 97db condition ($r = 0.02$, $p=0.95$) or in the 102db condition ($r = -0.19$, $p=0.50$).

For the money conditions there was no significant correlation between pleasantness and dwell time bias for A in the 10p condition ($r = 0.39$, $p=0.24$) or in the 50p condition ($r = -0.18$, $p=0.57$).

Post-hoc analysis: A further post-hoc analysis was conducted on anxiety ratings for the combined money CS+/- to try to ascertain the reason for the increase in dwell time bias for the CS+/- over block. A post-hoc paired t-test between anxiety for B in block 1 and anxiety for B in block 2 revealed that there was no significant increase in anxiety between these blocks (t(22) = 1.63, p=0.12).

Discussion

In general, dwell time data indicated that when a stimulus was predictive of a reward then attention was driven by the uncertainty of the stimulus in predicting the outcome in accordance with the Pearce and Hall (1980) theory, while dwell time biases in the noise conditions appeared to support the theory that it is the incentive value of a stimulus that attracts attention (Bindra, 1969; Lang et al., 1993).

In both of the money conditions dwell time biases indicated that attention was greater for the partial predictior (CS+/-) over the full predictor of the outcome (CS+). Furthermore, the CS+/- was selectively attended to over the X stimulus, while there was no such bias for the CS+ or CS-. This was not mirrored in the pattern of conditioned emotional responses: as predicted, the CS+ was rated as more pleasant than either the CS+/- or the CS-, and while the CS+ was rated as more pleasant in the 50p condition compared to the CS+ in the 10p condition, no more attention was allocated towards the CS+ in the 50p condition. Nor did attention match an alternative measure of incentive salience, arousal. As well as indicating that arousal was greater for the CS+ over the CS- in both reward conditions, skin conductance responses were greater for the CS+ in the 50p condition compared to the CS+ in the 10p condition. Such a divergence between the incentive value and the attentional data appear to contradict theories arguing that attention for conditioned stimuli is driven by the hedonic-affective value of rewards (Stewart et al., 1984), or by the incentive salience properties of rewards (Robinson & Berridge, 1993). The present findings do concur with a prior animal study, where attention for a partial predictor of a food reward was sustained across conditioning and attention for a full predictor of the outcome diminished as learning progressed (Kaye & Pearce, 1984). That said, there are some discrepancies in the dwell time data that appear to be problematic for an error-driven interpretation. According to error-driven models of attention, as learning progresses attention should become more efficient, and this may be reflected in the orienting responses. However, although there was some indication of a greater likelihood for the CS+ to be fixated to first relative to the CS+/- in the 10p condition, there was no evidence of such a trend in the 50p condition. That said, the absence of an orienting bias for the CS+ is not necessarily problematic for uncertainty theories of attention as the likelihood measure does not necessarily reflect a pure measure of the initial capture of attention. Indeed, in order for an overt orienting response to occur the stimulus must already have been detected, resulting in subsequent eye-movements becoming vulnerable to control from goal-directed processes. Thus, the likelihood to first fixation measure may become confounded by additional top-down processes. In addition to problems arising from this measure of attention, there were some aspects of the dwell time data that also did not fit with the prediction error model. Firstly, there was no significant decrease in attention to the CS+, which the model predicts should be present during the later stages of learning. However, such a discrepancy with the Pearce and Hall (1980) theory could be explained if the decrease occurred within the first block of conditioning and remained undetected. Another aspect of the current data that doesn't fit with a prediction error explanation is the increase in attention to the partial predictor across blocks of training, which was not matched in any change in learning according to expectancy ratings. One possible explanation is that attention for the CS+/- in the reward paradigm was partially driven by acquired unpleasantness related to the uncertainty of the outcome. However, post-hoc analysis revealed that this increase over block in dwell time bias was not matched by a concurrent increase in anxiety ratings for the CS+/-. In the absence of evidence for a relationship with anxiety the reason for the increase in attention to the CS+/- is outside the scope of the current investigation.

In contrast, when a stimulus predicted an aversive noise outcome, dwell time biases indicated that attention was allocated according to the aversiveness of the stimulus. On the whole, dwell times for the conditioned stimuli matched conditioned emotional responses for the stimuli. For both noise conditions, anxiety ratings were greater for the CS+ over the CS-, and this pattern was mirrored in the dwell time biases. In addition, the alternative measure of incentive value, autonomic arousal, also matched dwell time data as the skin conductance response was greater for the CS+ over the CS-. Although increasing the level of aversiveness in the current study did not significantly increase dwell time biases for the CS+, the mean values did indicate a trend for greater dwell times for the 102db CS+ compared to the 97db CS+. Indeed, conditioned incentive value as measured by autonomic arousal revealed that the CS+ (along with the CS+/- and the CS-) in the 102db condition was greater than for conditioned stimuli in the 97db condition, and for conditioned anxiety responses there was also a trend towards greater aversive emotionality for the 102db CS+ compared to the 97db CS+. The failure of significant differences in attention and emotional ratings between aversive intensity levels may be due to a lack of differentiation between the 97db and 102db outcomes. Even though instrumental avoidance responses obtained through a variable interval schedule did indicate a significant difference in aversive level between 97db and 102db outcomes, there was no difference according to affective ratings obtained pre-conditioning. Nevertheless, these trends in the data do indicate that increasing the incentive value of the stimulus increased attention, as was previously reported when increasing the aversiveness of an unconditioned stimulus (Mogg et al., 2000). That said, while the majority of evidence for the noise conditions supports the incentive hypothesis, some aspects of the current data do not entirely fit with the predictions of this model. Firstly, as hypothesised by some models, attention should be initially attracted to affective stimuli (E. Fox et al., 2000; Scherer, 2001), but this was not the case according to the likelihood to first fixation measure of attention; there was no difference in the likelihood of a CS+ or the CS- in attracting attention. However, the means for the likelihood measure did appear to reveal a trend that matched the dwell time biases, and as discussed in regard to the reward data, the likelihood measure may be confounded by other goal-directed processes. Secondly, ratings of emotional conditioning for the CS+ in the noise conditions were not correlated with the dwell time biases for the CS+. However, the affective ratings may not be a sensitive enough measure to correlate with dwell time bias as they were only acquired every 36 trials. A more sensitive measure of valence may be obtained through physiological measures such as the startle blink reflex, which could be measured on a trial-by-trial basis. Previous studies have found that modulation of the startle blink reflex differentiates pleasant, unpleasant, and neutral stimuli and is relatively uninfluenced by habituation effects (M. M. Bradley, Lang, & Cuthbert, 1993).

The findings for the aversive outcomes in the current study are significant as they contradict both Pearce and Hall (1980) and the findings from the study on which the current design is based (L. Hogarth, Dickinson, Austin et al., 2008). The discrepancy between the current findings and that of the previous study may be due to several factors. Firstly, the current design eliminated the confound of the participant being able to control the length of stimulus viewing time, which may have enhanced dwell times to the CS+/- in the Hogarth et al. (2008) study. Secondly, the current study employed a higher intensity level reinforcer (102db), and it may be that incentive stimuli must be at a certain level in order to overcome learning-driven mechanisms of attention. While no differences between the two levels of aversive intensity were detected in the current study, the mean dwell time biases revealed a trend towards a bias for uncertainty in the 97db condition as the mean for the CS+/- was greater than for the CS+, while the reverse pattern was apparent for means dwell times in the 102db condition (CS+/->CS+). It is plausible, therefore, that a lack of statistical power may have masked this difference, and that under conditions of low aversive intensity attention is mediated by prediction error.

The findings of the current study initially point towards qualitatively different mechanisms of attention in aversive and appetitive conditioning. Attention appeared to be mediated by the affective value of the stimuli in aversive conditioning, while attention for rewarding outcomes seemed to be driven by the uncertainty of the conditioned stimulus in predicting the outcome. These differences are unlikely to be related to a delay in learning in the aversive conditions as expectancy ratings indicated a more efficient learning of the stimulus contingencies for these conditions over the rewarding conditions. However, two lines of evidence indicated that the incentive intensity of the outcome may determine whether attention is mediated by prediction error, or by the incentive value. Firstly, in the noise conditions, dwell time bias means for the 97db conditioned stimuli indicated that attention may have followed error-driven mechanisms, while 102db dwell time bias values appeared to match arousal responses and affective ratings. This difference may have been masked by the number of levels incorporated in the analysis reducing the statistical power, resulting in a Type II error. Secondly, affective ratings of the outcome obtained prior to training indicated that there was not a significant difference between low and high levels of aversive intensity for either rewarding or aversive outcomes. In the noise conditions this may have contributed to the lack of significant differences in dwell time biases between aversive levels, while in the money conditions the incentive value associated with the outcome may not have been of a sufficient level to induce incentive-driven mechanisms. Indeed, the majority of studies where an attentional bias for appetitive stimuli has been reported have used highly rewarding drug stimuli (Hester, Dixon, & Garavan, 2006; Lubman et al., 2007; C. J. Morgan et al., 2008). If a drug outcome has a higher incentive value than a monetary outcome, it may be more efficient in eliciting incentive-driven attention. Such a possibility needs to be addressed in a future study. Moreover, even though conditioned autonomic arousal was matched between rewarding and aversive conditioned stimuli according to skin conductance responses, rewarding stimuli may need to be at a greater level of arousal relative to aversive stimuli in order to induce incentive-driven mechanisms of attention. Indeed, there is evidence that arousal gradients may be valence-specific, implying that different mechanisms control arousal within appetitive and aversive systems. This concept is supported by studies reporting that positive and negative emotions have different autonomic profiles (Collet, Vernet-Maury, Delhomme, & Dittmar, 1997), and that damage to the amygdala abolishes the arousal gradient for negative stimuli but not for positive stimuli (Berntson, Bechara, Damasio, Tranel, & Cacioppo, 2007). Thus, appetitive stimuli may need to be at an even higher level of incentive value relative to aversive stimuli to induce incentive-driven mechanisms of attention.

In conclusion, while the data support a role for incentive salience in attention for stimuli associated with aversive outcomes and prediction error in attention for stimuli associated with rewarding outcomes, the absence of incentive-driven mechanisms of attention for the monetary outcomes may be related to an insufficient activation of appetitive motivational systems.

5. Attention to conditioned stimuli predictive of a cigarette outcome

Experiment 5.1

Introduction

The findings from the prior study indicated that for monetary rewards attention was driven by prediction error, such that attention was greatest for a partial predictor (CS+/-) over a full predictor (CS+). In addition, even though the CS+ was rated as more pleasant than the CS-, there was no difference in attention between these two stimuli. However, numerous studies have indicated that rewarding stimuli tend to attract attention, creating a major discrepancy between the findings of experiment 4.1 and the literature on attention and reward. One reason for such a discrepancy may be connected to differences in the types of reward used. The majority of studies where attention has increased to rewarding stimuli have used stimuli associated with highly salient motivational rewards such as food or drugs. In a variety of dot-probe tasks, attention was reportedly greater for alcohol-related stimuli for heavy social drinkers (Townshend & Duka, 2001), for food cues when participants were hungry (Mogg, Bradley, Hyare, & Lee, 1998a), and for smoking cues in smokers (B. P. Bradley et al., 2008). In addition, manipulation of the incentive motivational value of stimuli has been shown to enhance attention for that stimulus. For example, one study reported that heavy social drinkers relative to light drinkers, were faster to respond to a probe that replaced the spatial location of alcohol-related stimuli, but not if it replaced a neutral stimulus (Townshend & Duka, 2001). Such findings support motivational theories of attention, which state that attention is mediated by the incentive salience of the stimulus (Lang et al., 1997; Robinson & Berridge, 1993). In contrast, monetary stimuli, (particularly at low levels such as those used in the current investigations) may have less motivational significance than drug stimuli for drug-users. Indeed, one study reported that there was no difference in attentional bias for neutral or monetary visual stimuli in non-drug and ex-drug users (C. J. A. Morgan, H. Rees, & H. V. Curran, 2008). Interestingly, an attentional bias was found for the monetary stimuli, but only in current ketamine-users who also demonstrated an attentional bias for ketamine-related stimuli. Thus, the attentional bias for the monetary stimuli in this group was most likely due to an association of the money stimuli with the drug outcome. Differences have also been reported in the areas of activation associated with monetary and drug rewards. Using various values of monetary outcomes (10p, 20p, 50p, £1) and measuring brain acitivty via fMRI, Elliot, Newman, Longe, & Deakin (2003) described how increasing the monetary value increased activation linearly in the premotor cortex, nonlinearly in the orbitofrontal cortex, while activity in the amygdala and striatum remained equal across all values of reward. In contrast, (Franklin et al., 2007) reported smokers' levels of cigarette craving in the presence of smoking cues was positively correlated with activity in the amygdala and striatum. Although the level of value was measured differentially between these two (i.e. increasing objective monetary value, versus changes in subjective value or "craving"), the differential pattern of responding in the striatum and amygdala does seem to suggest that drug stimuli activate some reward regions in a different manner to monetary stimuli, allowing for the possibility that mechanisms of attention may also be differentiated. Intuitively, drug stimuli are more related to concepts of “craving” and “desire” than monetary stimuli, even though both may be equally liked. It is this difference in motivational activation, therefore, that may account for the discrepancy in the attentional data in the current investigation and the addiction literature’s accounts of attentional biases for drug-related stimuli.

If attention is mediated by the affective value in high incentive outcomes only, then there should be evidence for this in the conditioning literature. However, when non-monetary reward outcomes are used in conditioning paradigms there are discrepancies in the attentional data, which need to be addressed. As previously described, prediction error-driven attention was demonstrated using food stimuli as the rewarding outcome - an orienting response diminished over time to a light CS predicting food reward in rats, whilst the orienting response was maintained for a partial reinforcer (Kaye & Pearce, 1984). However, in this particular study no measure of the incentive salience of the food reward was obtained, nor were comparisons made between hungry and satiated rats, so it is not known to what extent the food was a high incentive reward. In humans, one study reported that attention diminished over training for a CS+ associated with a cigarette outcome, implying that attention was error-driven even for a highly salient reward outcome (L. Hogarth et al., 2005). However, there are two possible reasons why attention may not have been governed by the rewarding properties in this paradigm. Firstly, participants were informed of the contingency outcomes prior to conditioning and consequently, in the absence of a strong motivation to attend to the stimuli (i.e. to learn the contingencies), they may not have developed a conditioned emotional response. Additionally, the CS+ also indicated than an instrumental response should be made as quickly as possible in order to obtain the cigarette outcome. Thus, the measure of attention may have been confounded by the motivation to obtain a reward as quickly as possible. The former explanation appears the most plausible as a subsequent conditioning study incorporating an instrumental response found an increased attentional bias for the CS+, even after contingency-learning had occurred (L. Hogarth, Dickinson, Hutton, Elbers et al., 2006). However, a partial predictor was not included in either of these designs, and thus a role for prediction error in guiding attention cannot be completely excluded. That said, Carter & Tiffany (2001), who did use a partial predictor, did provide some evidence that the affective properties of drug-predictive stimuli may determine the allocation of attention. They reported that when smokers were presented with stimuli signalling the availability of smoking a cigarette or drinking water at 100%, 50%, and 0% probabilities, increases in skin conductance, craving, positive mood, and speed to obtain the cigarette increased according to the predictive validity of the stimuli for the cigarette outcome, while there were no changes in any of these measures for the water-predicting stimuli. Increased skin conductance response is related to enhanced attention to stimuli (Lang et al., 1993), providing some support for the affective-attention hypothesis. Clearly, however, the absence of attentional measures in this study precludes any firm conclusions regarding the control of attention. In light of these discrepant findings in the animal and human literature, the current study sort to establish whether attention for a high incentive reward is driven by the affective properties of the stimulus as predicted by affective-motivational theories of attention (Lang et al., 1997; Robinson & Berridge, 1993), or if attention continues to be dominated by the prediction error (Pearce & Hall, 1980).

The current paradigm was adapted from the previous chapter in order to investigate whether a highly salient reward outcome would induce attention as mediated by affective mechanisms, Cigarettes were chosen as the outcome as they have been shown to be a highly motivating outcome in previous studies. Studies using nicotine have found that it induces motivated responding in both rats (Paterson & Markou, 2005) and in humans (L. Hogarth et al., 2005), while other studies have found that conditioned cues associated with nicotine potentiate DA release in the nucleus accumbens and prefrontal cortex in a similar manner to morphine (Bassareo, De Luca, & Di Chiara, 2007). Thus, nicotine appears to possess a high incentive reward value. Furthermore, the incentive value of cigarettes can be increased by depriving smokers such that they find smoking cues more pleasant and have stronger craving reactions in the presence of such cues compared to those that have not been nicotine-deprived (M. Field, Mogg, & Bradley, 2004). Thus, the incentive value of a cigarette reinforcer may be further manipulated to increase the likelihood that it will be a highly motivating reinforcer. ¼ of a cigarette was used as the unconditioned stimulus in the current investigation as this amount acted as a successful reinforcer in a previous study (L. Hogarth et al., 2005). Although a cigarette may be less of a high incentive outcome than nicotine, if participants were able to smoke during the experiment this may decrease the value of the outcome, and subsequently affective-driven mechanisms of attention may not become apparent.

Dwell time was used as before as a measure of attention. As well as measuring goal-directed behaviour, biases for conditioned incentive stimuli have also been shown to be present only at longer stimulus durations (B. P. Bradley et al., 2008; Mogg et al., 1998a) such that biases according to the incentive value should also be apparent at 3000ms presentations and reflected in longer dwell times. Further adaptations to the paradigm included summations of the reinforcer outcome, such that they received the sum of their outcomes every 12 trials, instead of receiving the outcome per trial. This was purely a practical measure to allow participants to move a whole cigarette rather than a ¼ of a cigarette.

In order to verify that the cigarette outcome was a high incentive outcome, a subjective measure of the incentive value for this outcome was obtained prior to conditioning. This measure was adapted from the subjective affective rating scale used in experiment 4.1. In addition, to increase the chances that the cigarette outcome would be highly motivating, smokers had to have smoked for a minimum of 6 months, currently smoke a minimum of 10 cigarettes per day and to have abstained from smoking for a minimum of 2 hours prior to the testing session. Such criteria have been incorporated in previous studies using smokers (L. Hogarth, Dickinson, & Duka, 2003; L. Hogarth et al., 2009; L. C. Hogarth et al., 2003). Measures of emotional conditioning were also retained from experiment 4.1 in order to examine the effects of affective value on attention. However, the author acknowledges that as hedonic value and motivational value are independent components of the affective significance of a stimulus (Balleine & Dickinson, 1991), there may be some dissociation between attention and emotional ratings of the stimuli. Finally, measures of nicotine dependence were also incorporated as the level of dependence may modulate attention for smoking cues. Indeed, studies have reported that less nicotine-dependent smokers exhibit increased attention for smoking cues relative to highly nicotine-dependent smokers (L. C. Hogarth et al., 2003; Mogg, Field, & Bradley, 2005). Thus, in the current study, measures of nicotine dependence were obtained in order to eliminate level of dependence as a possible confound. Furthermore, such measures should enable additional clarification of the relationship between the incentive salience value and attention.

Nicotine-dependence measures included subjective ratings of the number of years smoked and number of cigarettes smoked per day as these have both been shown to be correlated with attention (L. C. Hogarth et al., 2003) and with learning (L. Hogarth et al., 2003). Participants were informed that their carbon dioxide levels would be measured to ensure adherence with the conditions of abstinence. Measure of anxiety, depression, BIS and BAS, and age were retained as before, purely in the event that they may aid in the elimination of confounds in the data.

The following hypotheses were predicted: based on the evidence that drug cues have a high incentive value and attract attention, attention will be driven by the incentive value of the stimuli as expressed through an attentional bias for the CS+ over the CS-, even after learning has occurred. This effect should also be mirrored by the conditioned affective responses as measured by subjective pleasantness ratings of the stimuli.

Method

Subjects

16 subjects (8 male) aged between 18 and 48 (SEM 24.19 ± 2.14) participated in the experiment. Subjects were recruited using advertisements sent via email to students and staff at the University of Sussex who were members of a psychology subject pool. Subjects were only permitted to take part in the study if they were over 18 years of age, had no hearing difficulties, were not currently taking any anti-psychotic medication, and were in general good health. Subjects gave their informed consent before participating in the study,

which was approved by the University of Sussex ethics committee. All subjects received a payment of £10 at the end of the experiment. Participants were informed that this was the monetary equivalent of the cigarettes they had won during training, as it was against ethical guidelines to provide them with cigarettes.

Exclusion criteria:

As per the original design participants were excluded from the subsequent analysis if they failed to have significantly discriminated between the CS+ and CS- by the final block of training (final 24 trials) according to mean expectancy ratings.

Design

A 2-way within-subjects design was employed. The within-subject variables were CS type (3 levels: CS+, CS+/-, CS-) and block (3 level: block 1, block 2, block3). Subjects completed 144 trials of discriminative training.

Materials

Materials for conditioning sessions

<u>Conditioned stimuli:</u> The same visual stimuli were used as in experiment 3.1 and 4.1.

<u>Unconditioned stimuli:</u> 20 cigarettes of the participant's preferred brand were present in an open tin to the right hand side of the participant, while an empty tin in which to transfer cigarettes was on their left. Participants' transferred a total of 18 cigarettes.

Eye-tracking measures: Eye movements were tracked using an Eyelink II eye-tracker as used in experiment 3.1 and 4.1. Eye movements were measured throughout the whole of the discriminative training trials.

Questionnaires

In addition to the POMS, BIS/BAS and medical history questionnaires, participants answered questions relating to the number of cigarettes they smoked per day and the number of years they had smoked for, which provided additional measures of smoking dependence (see Appendix 4). All questionnaires were administered prior to discriminative training.

Visual Acuity

As before, in order to ensure that participants would be able to discriminate between the visual stimuli they took the Snellen 3-m visual acuity test to make sure their eyesight was at a minimum level of 20/30.

Procedure

Each subject was tested individually in one 50 minute session. This consisted of using the Snellen 3m acuity test to ensure visual eligibility and completion of consent form and questionnaires which took approximately ten minutes. The second part consisted calibrating the eyetracker device (approximately 5 minutes), then the participant provided a incentive value of the outcome, followed by 144 trials of discriminate conditioning trials. Each trial lasted approximately 8 seconds.

Initial procedures

Upon arrival, participants' visual acuity was tested, then they completed the consent form and questionnaires before being seated at a table approximately 100cm away from a desktop PC.

Outcome incentive value

Prior to discrimination training participants provided a rating of their desire for the reinforcer. They were presented with the question "How much would you like to smoke a cigarette? Use any of the keys 1 to 9 to answer. 1=not at all, 9=extremely".

Discriminative conditioning procedure

Discrimination training began with the following instructions: "Each trial will begin with a fixation cross (+) in the centre of the screen, which you should look at. Then two pictures will appear. Shortly afterwards you will be asked to rate how likely it is you will get a 1/4 cigarette on a scale of 1 to 9. Every 12 trials your total number of cigarettes will be calculated and you will be told to move this amount into your box. Press the space bar to begin." CS+, CS+/- and CS- stimuli were presented as part of a picture pair with a context stimulus X as per the previous experiments. After each presentation of the stimulus, participants were required to answer a question regarding their expectancy of the outcome. After which time they received the outcome or not depending on which stimulus had been presented. Participants received their total outcome every 12 trials. There were two sets of trials (each consisting of 12 trials) – one that totalled to 1 cigarette at the end of 12 trials and one that led to 2 cigarettes at the end of 12 trials. Within these trials the order of stimuli was randomised and between the two set of trials presentation of side of the screen was counterbalanced. There were two blocks, and order of block type followed this sequence (where 1 = 1 cigarette; 2 = 2 cigarettes): 1,2,2,1,1,2. At the end of every 12 trials (after they had received the total cigarette reward) they gave emotional ratings for the conditioned stimuli.

Trial sequence

Each trial proceeded in the following way: a fixation cross appeared in the centre of the screen and once the pupil was fixated on the centre of the cross the experimenter pressed the space bar on a separate computer and the cross disappeared to be replaced by a stimulus pair that remained on the screen for 3000ms. The stimulus disappeared to be replaced by the question “How likely is it you will receive 1/4 cigarette? 1 = not at all likely 9 = very likely”. Once subjects had responded the question disappeared and there was a 1050ms presentation of a blank screen. If it was a win trial then participants received the following feedback on the screen “You receive ¼ cigarette” for 2000ms. If it was a no-win trial then there was a blank screen for 2000ms. There was an additional 2000ms ITI between trials.

Emotional ratings

After every 24 trials participants were presented with the CS+, CS+/-, CS- and context stimulus X, where each stimulus was presented on it’s own twice. For half of the trials, presentation of the stimulus was followed by the question “How pleasant do you find this stimulus? 1 = not at all pleasant, 9 = extremely pleasant”. For the other half of the trials, presentation of the stimulus was followed by the question “How anxious does this stimulus make you feel? 1 = not at all anxious, 9 = extremely anxious”. Participants responded using any of the keys 1 to 9. Order of presentation of stimuli and question were randomised.

Statistical analysis

Corrections were made for all of the dependent variables such that any value 3 standard deviations above the mean was replaced with the mean of the level it was entered for analysis. Assumptions of all statistical procedures applied were checked. In the case of violation of the assumption of homogeneity of variances, the Greenhouse-Geisser adjustment was applied and adjusted degrees of freedom are reported. For significant main effects, post-hoc analyses with Bonferroni-corrected t-tests were used. All results were significant at $p<0.05$ unless otherwise stated. All analyses were performed using the Statistical Package of Social Sciences (SPSS 16).

Exclusion criteria:

Only those that became contingency aware were subsequently reported in the analysis. The criteria differed slightly from experiment 3.1 and 4.1 as participants were deemed contingency aware if expectancy ratings for A were significantly greater than for C in the final 24 trials rather than the final 36. This was purely due to differences in the way the trials were separated into blocks.

Variables measured during discriminative conditioning:

Expectancy ratings, dwell time bias (calculated as per the previous study), and pleasantness ratings were all analysed using 2-way within-subjects ANOVAs with CS type and block as the within-subject factors (3 levels: CS+, CS+/-, CS-; and 3 levels: (block 1, block 2, block 3). Likelihood to first fixation data was not analysed but is reported in Appendix 4.

Other analyses:

<u>Relationship between incentive salience and attention:</u> The relationship between the mean dwell time for A and the mean pleasantness rating for A was examined using Pearson's correlations coefficients. The incentive rating of the cigarette outcome obtained prior to conditioning was also added as a covariate in the dwell time 2-way ANOVA.

<u>Relationship between dependence and attention:</u> This was examined using Pearson's correlation coefficients between number of cigarettes smoked per day and mean dwell time bias for A, and number of years smoked and mean dwell time bias for A.

Results

Exclusion criteria: 3 subjects were excluded from the analysis for failing to fulfil the awareness exclusion criteria. Data for these 3 subjects are presented in Appendix 4.

Questionnaire data:

Table 5.1.1: Variables related to emotional and motivational baselines, and age of participants. Values are mean ± SEM (range in brackets)

Age	**Anxiety**	**Depression**	**BIS**	**BAS**
23.00 ± 1.75 (18-36)	0.68 ± 0.21 (-0.22-2.78)	0.52 ± 0.13 (0.00-1.60)	3.12 ± 0.10 (2.71-3.71)	3.11 ± 0.09 (2.68-3.62)

Table 5.1.2: Variables related to smoking dependency. Values are mean ± SEM (range in brackets)

Number of cigarettes per day	**Number of years smoked**
14.62 ± 1.00 (10-20)	6.46 ± 1.43 (2-20)

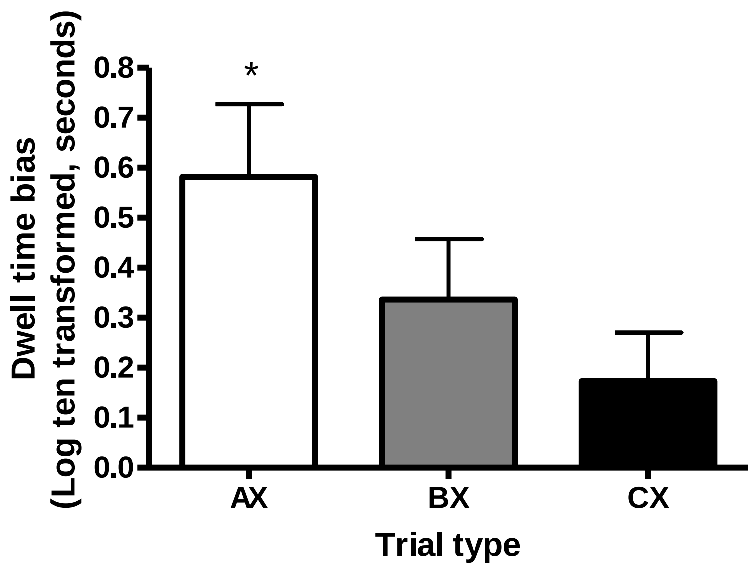
Outcome incentive value:

Mean incentive rating for the cigarette outcome was 6.77 ± 0.43.

Variables measured during discriminative conditioning:

Dwell time bias: Figure 5.1.1 shows a main effect of stimulus ($F(2,24) = 6.26$, $p<0.05$), indicating that the difference between A and B didn't quite reach significance ($F(1,12) = 3.41$, $p=0.09$), but that dwell time for A was significantly greater than for C ($F(1,12) = 9.73$, $p<0.05$). Furthermore, in order to ascertain whether there was an attentional bias for the C stimulus, a post-hoc t-test of dwell time for C revealed that it was not significantly different to zero ($t(12) = 1.76$, $p=0.10$).

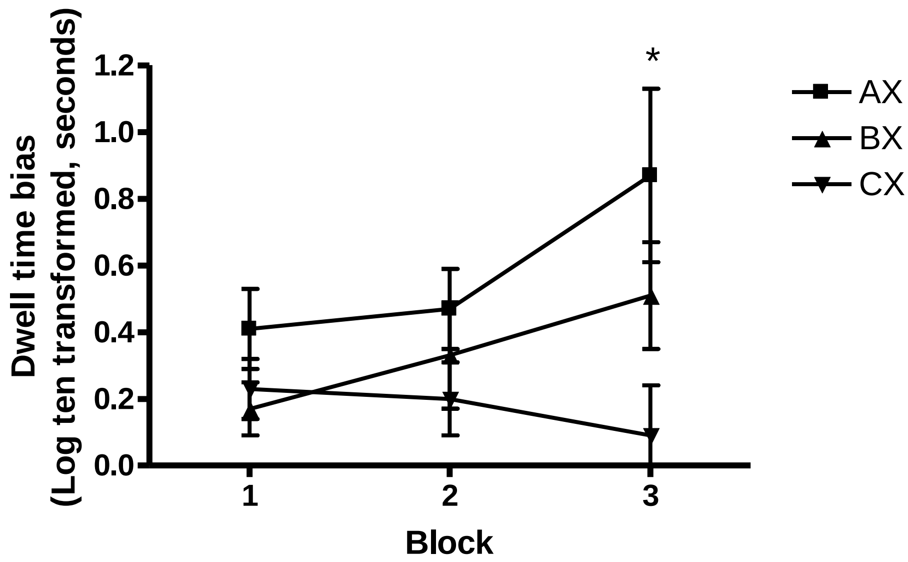
Figure 5.1.1: Dwell time bias values calculated by subtraction of context stimulus “X” from predictive stimuli A,B, and C on AX, BX and CX trials, measured during conditioning. Values are mean ± SEM



* = p<0.05 compared to CX

Figure 5.1.2 shows there was also a stimulus x block interaction ($F(4,48) = 3.88$, $p<0.05$). Contrasts revealed there were no differences between A and B over any of the blocks ($F(1,12)< 1.64$, $t>0.22$), and there was no significant difference between A and C between block 1 and block 2 ($F(1,12) = 0.51$, $p = 0.49$) while there was between block 2 and 3 ($F(1,12) = 12.24$, $p<0.05$). Post-hoc t-tests revealed that dwell time for A increased between block 2 and 3 ($t(12) = 2.24$, $p<0.05$), while dwell time didn’t change over these same blocks for C ($t(12) = 1.22$, $p=0.25$). An additional post-hoc t-test for the increase in dwell time for B between block 2 and 3 did not reach statistical significance ($t(12) = 1.80$, $p=0.10$).

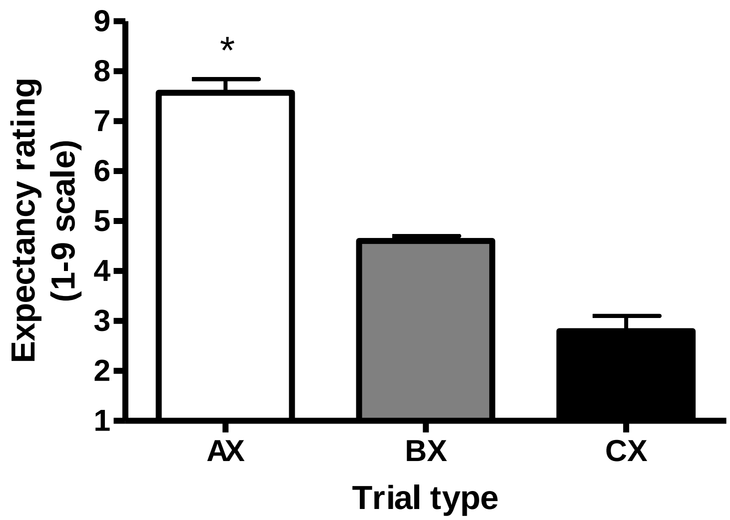
Figure 5.1.2: Dwell time bias values on AX, BX, and CX trials, divided into three blocks, measured during conditioning. Values are mean ± SEM



* = p<0.05 for AX in block 2 compared to AX in block 3

Expectancy ratings: Figure 5.1.3 shows a main effect of stimulus ($F(2,24) = 71.78$, $p<0.05$) indicating that expectancy for A was greater than for B ($F(1,12) = 155.58$, $p<0.05$), and greater than for C ($F(1,12) = 76.33$, $p<0.05$).

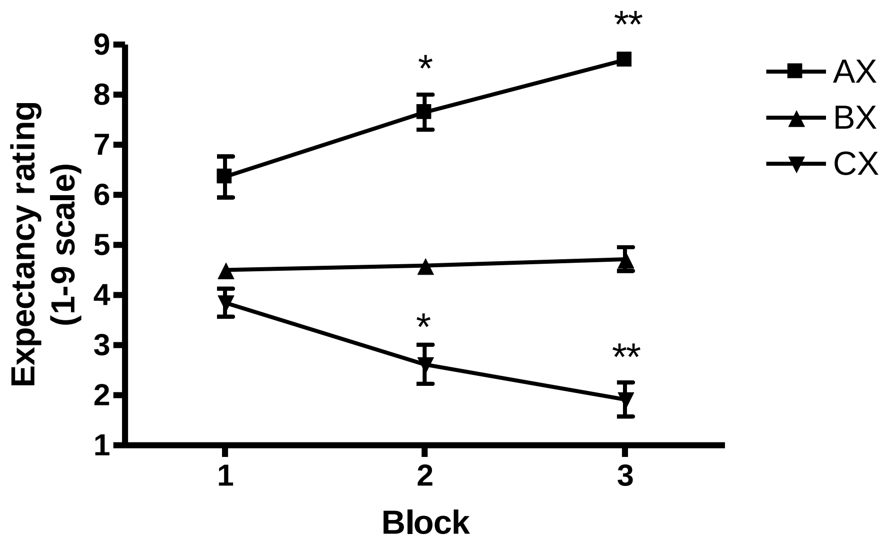
Figure 5.1.3: Expectancy ratings on AX, BX and CX trials, measured during conditioning trials. Values are mean ± SEM



* = p<0.05 compared to BX and CX

Figure 5.1.4 shows there was also a stimulus x block interaction ($F(4,48) = 32.27$, $p<0.05$), which revealed that all planned contrasts were significant: there was a significant difference between A and B over block 1 and 2 ($F(1,12) = 13.80$, $p<0.05$) and block 2 and 3 ($F(1,12) = 4.77$, $p<0.05$), and between A and C over block 1 and 2 ($F(1,12) = 46.25$, $p<0.05$) and block 2 and 3 ($F(1,12) = 20.24$, $p<0.05$). Post-hoc t-tests revealed that expectancy for A increased between block 1 and block 2 ($t(12) = 5.04$, $p<0.05$) and between block 2 and 3 ($t(12) = 3.85$, $p<0.05$), while expectancy for C decrease between block 1 and 2 ($t(12) = 4.14$, $p<0.05$) and between block 2 and 3 ($t(12) = 3.84$, $p<0.05$). Additional post-hoc t-tests were applied to verify the block within which learning discrimination took place. A paired-samples t-test confirmed that in block 1 there was a significant difference between A and C ($t(12) = 4.15$, $p<0.05$).

Figure 5.1.4: Expectancy ratings on AX, BX and CX trials, measured during conditioning and divided into three blocks. Values are mean ± SEM

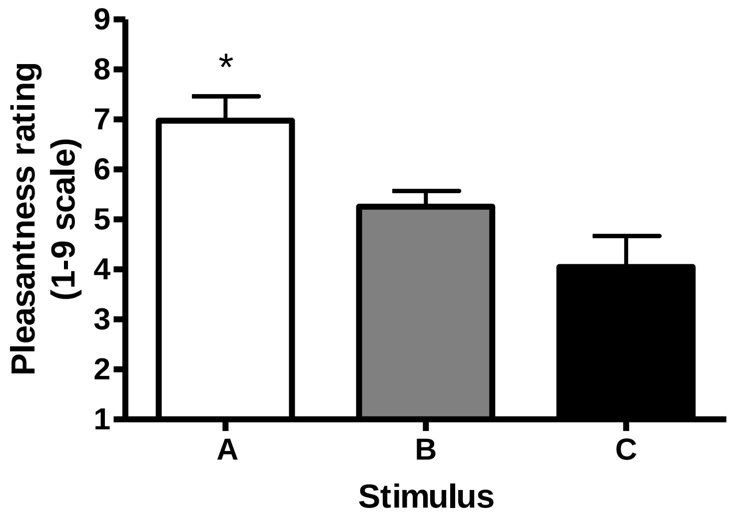


* = p<0.05 for AX and CX compared between block 1 and 2

** = p<0.05 for AX and CX compared between block 2 and 3

Pleasantness ratings: Figure 5.1.5 shows a significant main effect of stimulus ($F(2,24) = 7.89$, $p<0.05$) where repeated planned contrasts indicated that pleasantness ratings were higher for A over B ($F(1,12) = 11.25$, $p<0.05$), and over C ($F(1,12) = 8.61$, $p<0.05$).

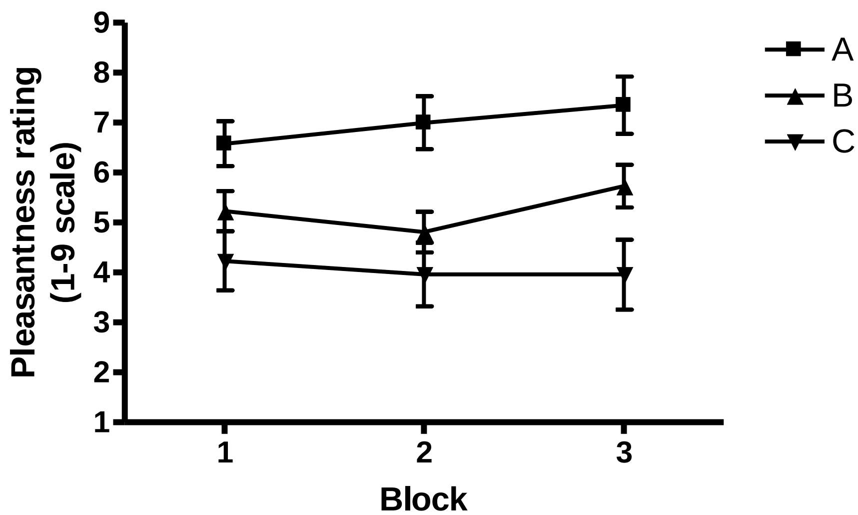
Figure 5.1.5: Pleasantness ratings for A, B, and C stimuli, measured after every 24 blocks of conditioning. Values are mean ± SEM



* = p<0.05 compared to B and C stimuli

Changes in pleasantness ratings over block for each stimulus are depicted in Figure 5.1.6. However, there was no stimulus x block interaction ($F(4,48) = 1.75$, $p=0.16$).

Figure 5.1.6: Pleasantness ratings for A, B and C stimuli measured after every 24 blocks of conditioning, and divided into three blocks. Values are mean ± SEM



Other analyses:

Relationship between incentive salience and attention:

a) There was no significant correlation between mean pleasantness ratings for the CS+ and dwell time bias for the CS+ (r = 0.25, p=0.41).

b) When the incentive value of the outcome was added as a covariate in the dwell time analysis, there was no longer a main effect of stimulus (F(2,22) = 2.25, p=0.13) or a stimulus x block interaction (F(4,44) = 0.34, p=0.86).

Relationship between dependence and attention:

a) *Number of cigarettes smoked per day*: there was no correlation with the number of cigarettes smoked per day and dwell time for the CS+ (r = 0.05, p=0.86).

b) *number of years smoked*: there was no significant correlation with the number of years smoked and dwell time for the CS+ ($r = -0.24$, $p=0.43$).

Discussion

Overall, results indicated that attention for the conditioned stimuli was mediated by the rewarding properties associated with the outcome. The conditioning process yielded attentional biases that were greater for the CS+ over the CS-, which persisted throughout the conditioning procedure. Emotional ratings, for the most part, matched this pattern of biases, implicating that attention was driven by the incentive value of the stimulus in accordance with incentive salience theories of attention (Lang et al., 1997; Robinson & Berridge, 1993). Further support for this hypothesis was achieved through using the incentive ratings of the outcome as a covariate, as when incentive ratings were held constant the dwell time biases disappeared. Prediction error theories of attention were not supported, as there was no evidence of a decrease in attention to the CS+, and attention was not greatest for the CS+/- at any time point. Such findings add additional support to a prior investigation where an attentional bias for a stimulus predictive of a cigarette outcome remained even after learning of the contingencies (L. Hogarth, Dickinson, Hutton, Elbers et al., 2006). The current data not only verify this finding but also demonstrate that a stimulus high in predictive uncertainty (CS+/-) will not be attended to more than a stimuli associated with a high incentive value (CS+).

While in general the pattern of attentional biases supports an incentive-driven mechanism, there are some aspects of the data that are problematic for this theory. Firstly, there was an element of mis-match between the emotional ratings and dwell time biases: The difference in dwell time bias for the CS+ over the CS+/- did not reach significance, while there was a significant difference for these two stimuli according to pleasantness ratings. In addition, the dwell time bias for the CS+ increased between the final two blocks in the absence of a concurrent increase in pleasantness ratings, and there was no correlation between pleasantness ratings and dwell time for the CS+. However, these discrepancies can be accounted for in several ways. Dwell time and subjective ratings may differ in their sensitivity in measuring attention and emotion respectively, implying that the absence of a significant difference between dwell times for the CS+ and CS+/- may be due to this measure being relatively less sensitive than subjective emotional ratings. Likewise, this interpretation could also explain the lack of a correlation between emotion and attention. The final discrepancy, the absence of a concurrent increase in emotionality for the CS+ during the final two blocks, may be related to an increased reactivity to the affective properties of the stimuli. That is, participants may have become more sensitive to the rewarding properties of the stimuli near the end of conditioning. Such an interpretation could account for the increased dwell time bias for the CS+ and the lack of an increase in subjective ratings of emotionality. An alternative explanation, which would also account for these discrepancies, is that attention was mediated by the motivational value of the conditioned stimuli, rather than the hedonic affective properties. It is plausible that the pleasantness ratings in the current study more closely reflected the associated hedonic value, dissociated from the motivational properties of the stimulus. Indeed, data from other conditioning studies has shown that motivation as measured by craving responses may control attentional biases rather than the hedonic value of the stimuli (L. Hogarth et al., 2003; Mogg et al., 2005). One study examining whether the affective or motivational value of smoking cues controlled attention reported that smokers attended more to both unpleasant and pleasant smoking-related stimuli compared to non-smokers, even though both groups differentiated pleasant and unpleasant stimuli in terms of subjective ratings (B. P. Bradley et al., 2008). It is important for future studies to clarify how conditioned stimuli associated with rewarding outcomes control attention, as while some theories stipulate that the hedonic value of a drug-associated stimulus captures and subsequently controls drug-seeking behaviour (Stewart et al., 1984), other theories state that the motivational salience of drug-related stimuli capture attention and control behaviour (Franken, 2003; Robinson & Berridge, 1993). The present study did attempt to clarify to some extent whether motivation or hedonic value were more related to attention through examination of the relationship between nicotine dependence level and attentional bias. However, correlational analysis indicated that attention for the CS+ was not related to any measure of dependence level. Initially, this appeared to contradict the motivational hypothesis as those with the highest dependence levels should also have the highest motivation to obtain the cigarette reward. However, previous studies have demonstrated that the relationship between nicotine-dependence and attention to smoking-related stimuli is complex. Years smoked and number of cigarettes smoked per day have been shown to be correlated with attention to smoking-related stimuli in previous studies but either in a quadratic (L. C. Hogarth et al., 2003) or negative (Mogg et al., 2005) relationship. There is clearly a complex and varied relationship between nicotine dependence and attention to cigarette cues, and this may explain the absence of a relationship between nicotine dependence and attention in the current study.

One clear limitation of the current study is the lack of clarification between motivational and hedonic influences. The findings of Mogg et al. (2005) that craving for a cigarette increased concurrently with attention for a cigarette cue does indicate that motivation may be the crucial factor that induces increased attention for stimuli predictive of highly salient rewards such as drugs. The current study did not use online measures of craving, and future studies should incorporate such online measures in order to elucidate the mechanisms through which attention for rewards is mediated. Furthermore, comparison of differing motivational values for the same rewarding outcome (i.e. through nicotine deprivation and satiety) would also help in clarifying some of these issues. Additional investigations into the stability of the attentional bias for a CS+ predictive of a drug outcome would also be of relevance as there are reports that under conditions where stimulus duration is under the control of the individual (as in experiment 3.1) attention for a conditioned stimulus predictive of a cigarette outcome may diminish once this outcome is fully predicted (L. Hogarth et al., 2009).

Attentional data in the current study contradict the pattern of attentional biases for the monetary outcomes in experiment 4.1, implying that when a conditioned reward is highly salient (such as when it predicts a drug outcome) attention is mediated by the appetitive properties of the stimulus, while attention for low incentive rewards (such as 10p and 50p) are mediated by prediction error, implicating differences in motivational salience as the mediator of these contrasting attentional mechanisms. However, caution must be taken with this hypothesis as no direct comparison was made between a monetary and a cigarette outcome. Furthermore, a slightly different methodology was used in the current study than that used in experiment 4.1, which casts some doubt onto whether the change in attentional biases was purely related to the change in reinforcer. That said, the methodology used in the current study should not have biased attention towards the rewarding properties of the stimuli – if anything, the control of incentive-driven mechanisms of attention should have been diminished as the actual receipt of the cigarette outcome was delayed. Indeed, studies using delay discounting tasks (a task measuring preference for immediate over delayed rewards of a larger value) comparing smokers and non-smokers (Ohmura, Takahashi, & Kitamura, 2005; Reynolds, Richards, Horn, & Karraker, 2004) reported that smokers have a greater tendency to discount delayed rewards relative to non-smokers (i.e. they value immediate over delayed rewards to a greater extent than non-smokers). Thus, the delay in receipt of the cigarette outcome in the current study may have actually reduced the incentive value of the outcome for the smokers, making it unlikely that the addition of a delay increased attentional biases for conditioned stimuli according to their rewarding properties.

6. Mechanisms of attention for conditioned stimuli in an aversive instrumental conditioning paradigm

Experiment 6.1.

Introduction

The data from chapter 4 indicated that conditioned stimuli predictive of an aversive outcome were attended to as a result of their affective properties rather than their uncertainty in predicting the outcome. However, it is not clear whether such effects would still be present in an instrumental conditioning paradigm. It is important to confirm whether or not the emotionality of the stimulus continues to drive attention when the conditioned stimulus signals a response should be made. Firstly, in everyday situations a stimulus that signals an aversive event is about to occur, also often signals that a response can be made in order to avoid the aversive event. Secondly, prediction error mechanisms are thought to be required in order to make decisions regarding what action to take; in a scenario where an instrumental response is contingent upon the knowledge of the outcome, attention may become biased towards stimuli according to their associated prediction error.

In order to make inferences regarding how attention may be mediated during instrumental conditioning, it is important to firstly elucidate how an avoidance response is controlled through associative processes. There are several theories regarding the mechanisms of avoidance learning, and how an instrumental avoidance response is controlled – such theories may be generally divided into cognitive and non-cognitive categories. Cognitive theories state that explicit knowledge of the associative relationships (CS, US, response, and outcome) mediates the avoidance response, while non-cognitive theories do not infer that such knowledge is necessary. According to one non-cognitive theory, an avoidance response is in fact an escape response towards a fear-evoking stimulus - the avoidance response is reinforced by the termination of the aversive CS (Mowrer, 1947). In this case knowledge of the CS-US relationship and knowledge of the response-no US relationship are not necessary factors in avoidance learning. Likewise, (Bolles, 1970) proposed that the avoidance response was reinforced by the rewarding feedback of the absence of the noise. Thus, in this theory also, knowledge of the CS-US contingencies have no importance in avoidance learning. In contrast, Rescorla & Solomon (1967) emphasised the importance of the CS-US relationship in controlling instrumental behaviour. Although this is a general model of instrumental behaviour (i.e. it doesn't separate instrumental responses for rewarding and aversive outcomes) it clearly relates to the control of avoidance responding: according to this theory, the instrumental response is maintained by the reinforcer contingency between the response and the outcome, while the capacity of the CS+ to elicit the instrumental response is acquired through the Pavlovian contingency between the CS+ and the outcome. Cognitive aspects have subsequently been developed from this model to explain avoidance behaviour. For example, Seligman & Johnston (1973) stipulated that while knowledge of the CS-US relationship is not essential, cognitive knowledge of the response-no US relationship controls the avoidance response. Lovibond, Saunders, Weidemann, & Mitchell (2008) took this theory a step further and proposed that cognitive knowledge of both the CS-US relationship and of the response-no US relationship are combined to control avoidance responses. That is, individuals acquire conscious propositional knowledge that an avoidance response can prevent the occurrence of an expected US. While there is some evidence in support of each these theories, the Lovibond et al. (2008) theory appears to have the strongest line of support. In particular, Declercq, De Houwer, & Baeyens (2008) recently conducted an experiment providing apparently unequivocal support for the cognitive-expectancy theory of avoidance behaviour. In this study participants were trained that stimulus A predicted a shock (US1), stimulus B predicted a loud noise (US2) and stimulus C predicted both aversive outcomes (US1+US2). In the next phase participants were trained that in the presence of C one response (R1) led to avoidance of the US1 but not the US2, while another response (R2) led to the avoidance of US2 but not US1. In the final stage participants were presented with A and B stimuli from the first phase and a measure was obtained of whether they selected the appropriate avoidance response or not. They reported that only participants who acquired knowledge of the contingencies made the appropriate response, and that those who were contingency-aware used this propositional knowledge to select the correct avoidance response. Such findings are problematic for the Mowrer (1947) theory as according to his model no discriminatory response should have been made in the presence of A or B as both type of responses were avoidance responses. It is also problematic for Seligman & Johnston (1973) as only those who were aware of the CS-US contingencies made the correct avoidance response in the presence of A and B.

If, as Lovibond and Shanks propose, the expectancy of an outcome mediates avoidance responding, it is plausible that in an instrumental conditioning paradigm the uncertainty of the conditioned stimulus controls attention in line with the Pearce and Hall (1980) predictions. Indeed, evidence indicates that prediction errors related to conditioned stimuli are important in decision-making processes such as whether to make an instrumental response. Pessiglione, Seymour, Flandin, Dolan, & Frith (2006) conducted a study where they found evidence that dopamine-dependent prediction errors were related to reward-seeking behaviour in humans. Healthy participants treated with L-DOPA (an enhancer of Dopamine function) had stronger prediction error signals in the striatum as indicated through enhanced BOLD signalling, and had a greater propensity to choose the most rewarding action to obtain a reward relative to individuals treated with haloperidol (a reducer of Dopamine function). Thus, these findings suggest that prediction errors are used to influence future decisions. It is conceivable that under conditions where the motivation differs (i.e. Pavlovian versus instrumental learning) attention may be modulated according to goal-driven processes. Indeed, the ability of top-down goal-driven processes in controlling attention is well-documented. Ferrari, Codispoti, Cardinale, & Bradley (2008) found that task-relevance could modulate controlled attentional processes - when affective pictures were presented as targets late positive potential (LPP) amplitudes (an EEG component associated with attention) were enhanced relative to when they were presented as non-targets. Thus, top-down goal-directed processes can be used to bias attention to attend to certain salient features of a stimulus. In relation to mechanisms of attention in avoidance learning, if the motivation to make an instrumental response requires attending to the associated prediction error of a stimulus then attention may switch to attending to this feature in order to decide whether or not to make the avoidance response.

There is some evidence to support the notion that during avoidance responding emotional mechanisms of attention may be over-ridden. Several studies have indicated that aversive conditioned stimuli induce less autonomic arousal when an avoidance response is introduced. Delgago, Jou, Ledoux, & Phelps (2009) reported that skin conductance responses for a CS predictive of shock were higher than for a CS predictive of the ability to avoid the shock. Lovibond, Saunders, Weidemann, & Mitchell (2008) also found that when an avoidance response for a shock outcome was introduced in Pavlovian training, arousal as measured by skin conductance response diminished for the CS+ and continued to diminish as avoidance training progressed. As autonomic arousal is associated with the orientation of attention (Lang et al., 1993), such a reduction in skin conductance response may reflect a reduction in attention to the CS+. In addition, there is evidence that the processing of a stimulus from as early as the stages of stimulus detection may be differentiated according to whether the stimulus has Pavlovian or instrumental associations. Cohen & Castro-Alamancos (2007) conducted a study using rats that were trained in a learning paradigm where an electrical somatosensory stimulus (CS) either signalled that a response could be made in order to avoid an aversive event (active avoidance) or signalled the occurrence of the aversive event (Pavlovian). Lesions to the somatosensory thalamus and superior colliculus contralateral to the CS blocked performance in the active avoidance task, while a lesion only of the somatosensory thalamus contralateral to the CS blocked performance in the Pavlovian task. Such findings indicate that while a CS associated with an active avoidance response may be detected through either pathway, Pavlovian CSs are detected only through the somatosensory thalamus. Thus, stimuli associated with an avoidance response may activate different mechanisms of attention to stimuli associated only with an aversive outcome.

However, some motivational theories have proposed that the psychophysiology of emotion is based on action dispositions, eg. heightened autonomic arousal and vigilance in preparation for mobilization of action (Lang et al., 1997; Lang & Davis, 2006). A study by Low, Lang, Smith, & Bradley (2008) seemed to foster some support for this model, as when cues predicting threat or reward loomed nearer to the participant physiological responses indicated increases in vigilance and autonomic preparation for action. Thus, if affective responses are based on activations of action-based motivational systems, a stimulus that signals an avoidance response may enhance attention to a greater extent via enhanced physiological activation, including heightened vigilance. Indeed, (Hajcak et al., 2007) reported that passively viewing both pleasant and unpleasant affective stimuli enhanced the excitability in the motor cortex while neutrally affective stimuli did not, indicating that emotional stimuli activate motivational action systems. As such, these theories make contradictory predictions to the error-driven theories of Pearce and Hall (1980) because they assume that the avoidance response activates aversive motivational systems to a greater extent than a Pavlovian conditioned stimulus, and consequently should attract more attention than a less motivationally relevant stimulus.

In order to investigate whether attention would still be mediated by the incentive value of a stimulus, even when the stimulus signals an avoidance response could be made, the same conditioning procedure was applied as in the previous chapter (experiment 4.1) but with an additional avoidance response option. Pavlovian conditioning trials were followed by instrumental conditioning trials where an avoidance response was introduced. Pavlovian training was included in addition to the instrumental training in order to ensure that participants would experience CS-US associations and develop a conditioned affective response to the CS. The inclusion of Pavlovian trials prior to instrumental conditioning was also found to enhance instrumental learning relative to when Pavlovian and instrumental conditioning was intermixed (Lovibond et al., 2008). The amount of Pavlovian training participants received in the current paradigm was based on a post-hoc analysis of the expectancy data from experiment 4.1 indicating that the CS+ was discriminated from the CS- by the end of the first 72 trials ($t(15) = 6.58$, $p<0.05$). This was to ensure that some level of learning discrimination and emotional conditioning should have occurred prior to instrumental training. Thus, 72 trials of Pavlovian conditioning trials were incorporated prior to instrumental conditioning. During the instrumental conditioning phase, avoidance responding was measured using a variable interval schedule, also described in chapter 4.1. A variable interval schedule was chosen in order to increase the likelihood of participants acquiring discriminatory responding between stimuli varying only slightly in reinforcement magnitude (eg. a CS+ vs a CS+/-). For example, (Glautier et al., 1998) found that the variable interval schedule generated greater response rates for a 1.5 pence reinforcer over a 0.5 and 0.1 reinforcer, indicating that even where there is very little difference in reinforcer value (as may exist between the CS+ and CS+/- in the current study), it is a highly sensitive measure of motivation. Moreover, the schedules of reinforcement were arranged such that for the CS+ a response terminated the noise on only half of the trials, while for the CS+/-, the response terminated the noise on half of the trials on which the noise was scheduled to be received. This was done to ensure that the CS+ maintained its incentive value during the instrumental conditioning phase (i.e all participants would experience the noise outcome in the presence of the CS+ during avoidance training). Thus, a reduction in attention to the CS+ in the instrumental phase was less likely to be a consequence of a reduction in the affective value of the CS+. Dwell time biases were used to measure attention as before, but likelihood to first fixation was no longer analysed as data from the prior study indicated that the likelihood of fixation was a less sensitive measure of dwell time, and thus did not reflect a different component of attention. However, this measure of attention will reported in Appendix 5. As with previous designs, only those who became aware of the Pavlovian contingencies were included in the analysis. According to Lovibond & Shanks (2002) only participants who become aware of the Pavlovian contingencies will be able to make discriminatory avoidance responses, as they use the knowledge of the CS-US contingencies in combination with instrumental contingencies in order to guide responses. Consequently, in order to test the hypothesis that the uncertainty of the conditioned stimulus in predicting the outcome guides attention in avoidance learning, only those who acquire explicit knowledge of the contingencies can be used. Finally, the 102db was chosen as the aversive outcome in the current design as behavioural and physiological data from the previous study indicated that the 102db noise was more motivating than the 97db noise, and hence more likely to induce discriminatory avoidance responses.

The predictions from the current study were that if goal-directed attention (resulting from the motivation to make an avoidance response) inhibits the control of incentive attention and biases attention for uncertainty, attention should decrease for the CS+ between Pavlovian and instrumental blocks, and continue to decrease as instrumental training progresses. In contrast, if the addition of the avoidance response imbibes the CS+ with additional incentive salience, in accordance with action-based theories of emotionality (Lang et al., 1997), then attention for the CS+ should increase between Pavlovian and instrumental blocks of training.

Methods

Subjects

16 participants (8 male) aged between 19-27 (SEM 20.69 ± 0.56) were recruited from the student population at the University of Sussex. All Participants had 20:20 or 20:30 vision and gave informed written consent. None of them had hearing difficulties, or were currently taking anti-psychotic medication. Participants were randomly assigned to 1 of 4 counterbalanced conditions. The University of Sussex ethics committee approved the study. Participants were paid £5 and for their participation in the study.

Design:

A 2-way within-subjects design was employed. The within-subject variables were CS type (3 levels: CS+, CS+/-, CS-) and block (4 level: block 1, block 2, block3, block 4). Block 1 and 2 were during the Pavlovian conditioning trials, while block 3 and 4 were during the instrumental conditioning trials.

Materials

Materials for conditioning sessions

Conditioned stimuli: The same four stimuli were used for the conditioned stimuli as were used in the previous study. As before, eye measurements were made using an Eyelink II eye tracker.

Unconditioned stimuli: The outcome was a 102b white noise lasting 40 milliseconds presented binaurally through PX200 Sennheiser headphones.

Eye-tracking measures: Eye movements were tracked using an Eyelink II eye-tracker as used in experiment 3.1 and 4.1. Eye movements were measured throughout the whole of the discriminative training trials.

Questionnaires

As in experiments 3.1 to 5.1 a medical history questionnaire ensured that participants were in general good health and adhered to the exclusion criteria. The POMS (McNair, Lorr, & Doppleman, 1971) was used to measure participant's current anxiety and depression level, and a BIS and BAS questionnaire (Carver and White, 1994) assessed the strength of participants' level of activation of systems regarding reward and punishment.

Visual Acuity

As used in experiments 3.1 to 5.1, in order to ensure that participants would be able to discriminate between the visual stimuli they took the Snellen 3-m visual acuity test to make sure their eyesight was at a minimum level of 20:30.

Procedure

The study lasted approximately 45 minutes for each participant. After the participants filled in the questionnaires described in the materials section, and gave their written informed consent they were given the Snellen 3-m visual acuity test. All participants were then seated at a table with a desktop PC in front of them, and the eye tracker device and headphones were attached to their head. Eye movement was then calibrated by the experimenter using the Eyelink II program. After participants provided an affective ratings of the noise outcome, there then followed 96 trials of Pavlovian discriminative training for the different stimulus contingencies, followed by a further 96 trials of avoidance training. Participants were then debriefed as to the purpose of the experiment and received appropriate monetary payment. The experimenter was present for all stages of the procedure.

Initial procedures

Participants visual acuity was measured to ensure they had a minimum of 20:30 vision. They then completed the questionnaires described in the materials section.

Pavlovian discrimination training

Pavlovian training followed the procedure outlined in experiment 5.1 with a few minor adjustments. The delay between the expectancy rating and receiving the outcome was extended to 4 seconds in order to match the delay during the variable interval schedule during the subsequent instrumental phase. In addition, the emotional questions were presented after every 24 trials.

Instrumental discrimination training

After Pavlovian training was completed participants were presented with the following instructions: *"Now you will sometimes be able to cancel the loud and unpleasant noise by pressing the space bar after you have made your expectancy rating. You can press the space bar as little or as much as you like. Holding the space bar down will not work, it has to be pressed repeatedly. Press the space bar to begin."*

Instrumental training followed the same procedure as the Pavlovian training except there was a 4-second variable interval schedules after participants had made their expectancy rating in which participants could press a space bar in order to avoid the noise. The 4-second VI schedule followed the programming used in experiment 4.1. If participants did not press in the given time-window then they received a 40ms blast of 102db noise. If they did press within the time window they did not receive the noise. In order to maintain the aversive qualities of the CS+ during this phase, a response was only effective on 50% of the trials, and would always occur during the other 50%. Consequently, for the CS+/- trials a response was only effective in stopping a scheduled noise in 25% of trials but was ineffective in stopping a scheduled noise on 25% of the trials; for the remaining 50% of the trials they weren't scheduled to receive the noise.

Statistical analysis

Corrections were made for all of the dependent variables such that any value 3 standard deviations above the mean was replaced with the mean of the level it was entered for analysis. Assumptions of all statistical procedures applied were checked. In the case of violation of the assumption of homogeneity of variances, the Greenhouse-Geisser adjustment was applied and adjusted degrees of freedom are reported. For significant main effects, post-hoc analyses with Bonferroni-corrected t-tests were used. All results were significant at $p<0.05$ unless otherwise stated. All analyses were performed using the Statistical Package of Social Sciences (SPSS 16).

Exclusion criteria:

Participants were excluded from the subsequent analysis if they failed to have statistically significantly discriminated between the CS+ and CS- by the end of Pavlovian training (final 36 trials) according to mean expectancy ratings.

Variables measuring attention during Pavlovian and instrumental conditioning:

<u>Dwell time bias:</u> The total looking time (dwell time) for each stimulus on every trial was recorded and log transformed. Dwell time bias was calculated by subtracting the dwell time for the context stimulus X from the dwell time for the predictive stimulus (A, B, or C).

These bias scores were subsequently analysed using a 2-way ANOVA with predictive value (3 levels: CS+, CS+/-. CS-) and block (4 levels: 1,2,3,4) as the within-subjects variables.

Likelihood of first fixation: Likelihood of first fixation was measured in accordance with the previous study and the mean values for each stimulus in each condition are reported in Appendix 5.

Variables measuring learning during Pavlovian and instrumental conditioning:

Expectancy ratings were analysed using a 2-way ANOVA with predictive value (3 levels: CS+, CS+/-. CS-) and block (4 levels: 1,2,3,4) as the within-subject variables.

Variables measuring emotion during Pavlovian and instrumental conditioning:

Anxiety ratings were analysed using a 2-way ANOVA with predictive value (3 levels: CS+, CS+/-. CS-) and block (4 levels: 1,2,3,4) as the within-subject variables.

Variables measuring avoidance responses during instrumental conditioning only:

Number of responses: To obtain behavioural measures of motivation to avoid or gain the stimuli the *response rate* was calculated as the mean number of times they pressed the spacebar over the ten variable interval trials. This value was then analysed using a 2-way within-subjects ANOVA with predictive value (3 levels: CS+, CS+/-. CS-) and block (2 levels: 3,4) as the within-subject variables.

Probability of a response: The probability that a response would be made was calculated as the number of trials on which at least one instrumental response was made. Chi-square analysis was performed on the total number of trials on which a response was made for CS+ trials compared to the total number of trials on which a response was made for the CS-.

Other analyses:

Relationship between attention and conditioned anxiety ratings: The relationship between emotion and attention for the CS was further investigated by analysing Pearson's correlation coefficients for the mean dwell time bias of the CS+ and the mean anxiety ratings for the CS+ separately during Pavlovian and instrumental phases.

Relationship between attention and incentive value of the outcome: The relationship between incentive value of the outcome and attention was investigated by adding the aversive rating of noise outcome as a covariate in the dwell time bias ANOVA.

Results

Exclusion criteria:

3 participants were excluded as they failed to acquire contingency awareness by the final 36 trials of the Pavlovian conditioning phase. Data for these 3 participants is included in Appendix 5. 13 participants were included in the subsequent analysis.

Questionnaires:

Table 6.1.1: Participant variables measuring baseline mood and appetitive and aversive motivation. Values are mean ± SEM

Anxiety	Depression	BIS	BAS	Age
0.52 ± 0.19	0.56 ± 0.18	2.89 ± 0.11	2.85 ± 0.12	20.08 ± 0.40

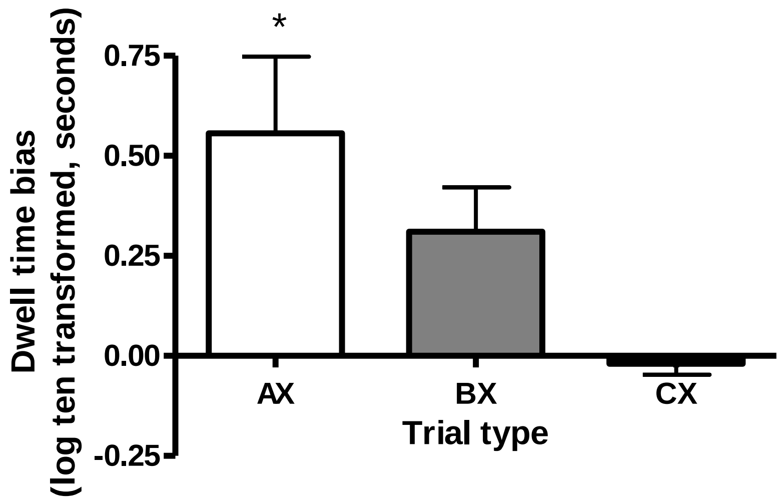
Outcome affective value: The mean unpleasantness value of the unconditioned stimulus was 6.00 ± 0.62.

Variables measuring attention during Pavlovian and instrumental conditioning:

Dwell time bias: There was a main effect of block ($F(1.98, 23.70) = 4.47$, $p<0.05$), but planned repeated contrasts did not reveal any significant interactions. As this was not a predicted effect it was not investigated further. However, in general means indicated that there was an increase in dwell time bias for all stimuli from block 1 (SEM 0.28 ± 0.06) to block 4 (SEM 0.50 ± 0.18).

Figure 6.1.1 shows a main effect of stimulus ($F(2,24) = 6.61$, $p<0.05$), indicating that there was no significant difference between A and B dwell time bias ($F(1,12) = 2.08$, $p=0.17$), but that A dwell time bias was greater than C dwell time bias ($F(1,12) = 9.19$, $p<0.05$). Post-hoc t-tests to zero indicated that A ($t(12) = 2.91$, $p<0.05$) and B ($t(12) = 2.79$, $p<0.05$) were significantly different from zero, but that C was not ($t(12) = 0.74$, $p<0.05$).

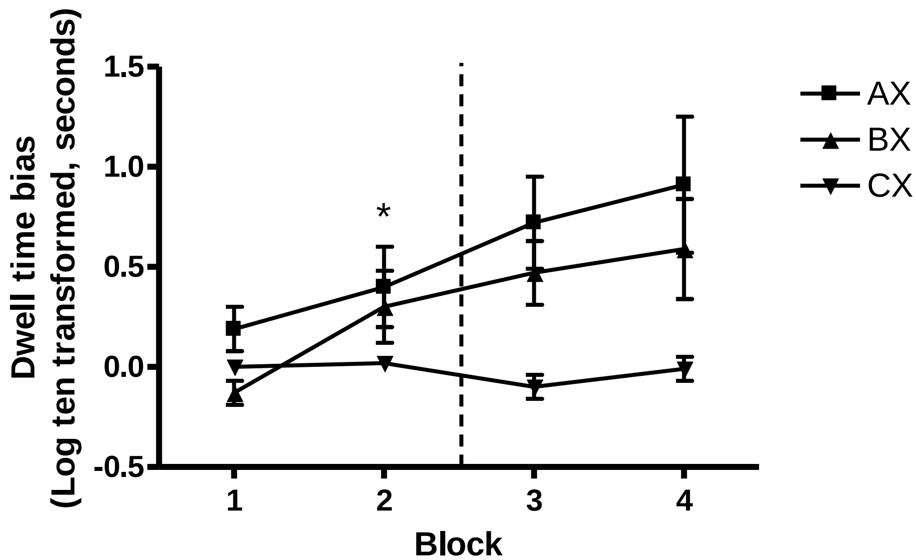
Figure 6.1.1: Dwell time bias values calculated as context dwell time (X) subtracted from the predictive stimulus dwell time (A, B or C) on AX, BX, and CX trials, collapsed across Pavlovian and instrumental conditioning phases. Values are mean ± SEM



* = p<0.05 compared to CX

Figure 6.1.2 shows that there was also a stimulus x block interaction ($F(6,72) = 3.32$, $p<0.05$), indicating that while there was no significant interaction between A and B for any of the planned interactions ($F(1,12) < 0.90$, $p > 0.35$), there was a significant interaction between A and C between block 2 and block 3 ($F(1,12) = 6.80$, $p<0.05$). Post-hoc t-tests indicated that there was a significant increase in dwell time bias for A between block 2 and 3 ($t(12) = 2.29$, $p<0.05$), while the decrease in dwell time bias between block 2 and 3 did not reach significance for C ($t(12) = 1.70$, $p=0.12$). However, the increase in dwell time bias between block 2 and 3 for B did not reach significance ($t(12) = 1.12$, $p=0.29$).

<u>Figure 6.1.2: Dwell time bias values on AX, BX and CX trials, divided into four blocks of conditioning trials. The dotted line represents the separation between Pavlovian and instrumental blocks. Values are mean ± SEM</u>



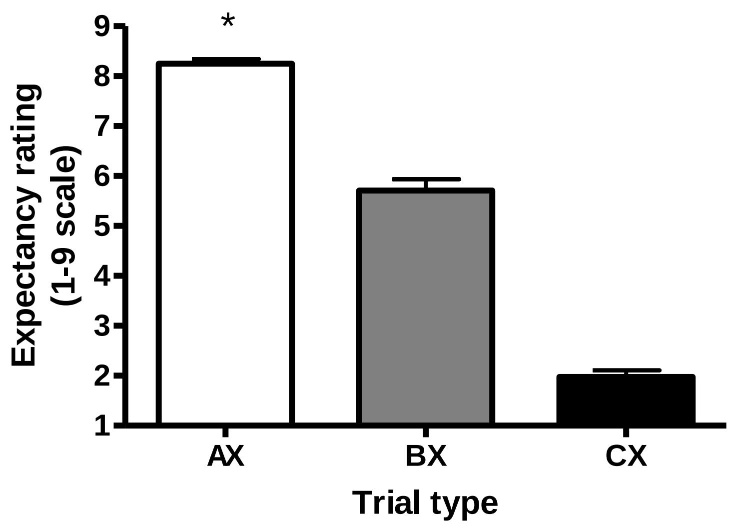
* = p<0.05 for AX in block 2 compared to AX in block 3

Variables measuring learning during Pavlovian and instrumental conditioning:

<u>Expectancy ratings:</u> There was a main effect of block ($F(3,36) = 5.53$, $p<0.05$), where repeated contrasts showed a significant difference between block 1 and 2 ($F(1,12) = 6.45$, $p<0.05$) and between block 3 and 4 ($F(1,12) = 8.71$, $p<0.05$). The means indicated that overall expectancies decreased between block 1 (SEM 5.56 ± 0.09) and block 2 (SEM 5.27 ± 0.07), while expectancies increased between block 3 (SEM 5.08 ± 0.12) and block 4 (SEM 5.33 ± 0.12).

Figure 6.1.3 shows a main effect of stimulus ($F(2,24) = 316.16$, $p<0.05$), where overall expectancies for A were greater than for B ($F(1,12) = 116.02$, $p<0.05$), and A was greater than C ($F(1,12) = 955.49$, $p<0.05$).

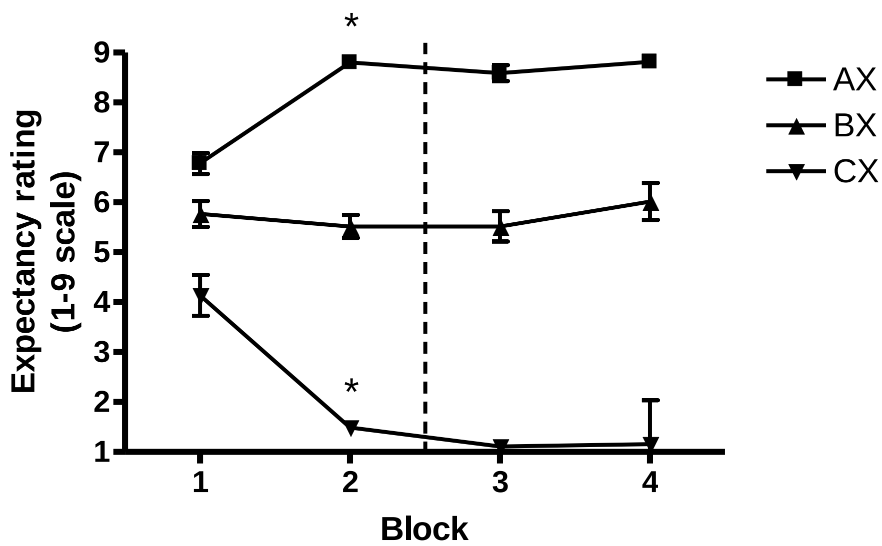
Figure 6.1.3: Expectancy ratings on AX, BX, and CX trials, collapsed over Pavlovian and instrumental conditioning phases. Values are mean ± SEM



* = p<0.05 compared to BX and CX trials

In addition, Figure 6.1.4 shows a stimulus x block interaction ($F(2.72, 32.67) = 36.94$, $p<0.05$), indicating that there was a significant interaction between A and B between block 1 and 2 ($F(1,12) = 58.48$, $p<0.05$), and between A and C between block 1 and 2 ($F(1,12) = 91.10$, $p<0.05$). Post-hoc t-tests indicated that expectancy for A increased between block 1 and 2 ($t(12) = 9.56$, $p<0.05$), expectancy for B remained the same ($t(12) = 1.33$, $p=0.21$), while expectancy for C decreased between block 1 and 2 ($t(12) = 7.59$, $p<0.05$).

Figure 6.1.4: Expectancy ratings on AX, BX, and CX trials, divided into four blocks of conditioning trials.The dotted line represents the separation between Pavlovian and instrumental blocks. Values are mean ± SEM

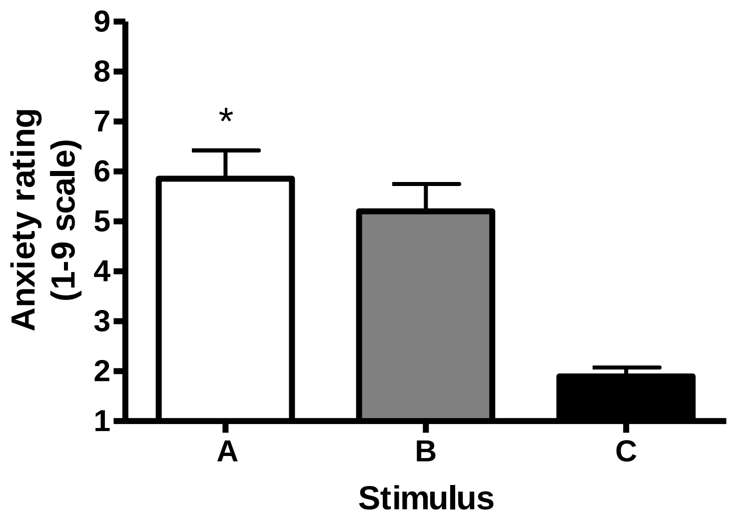


* = p<0.05 for AX and CX between block 1 and block 2

Variables measuring emotion during Pavlovian and instrumental conditioning:

Anxiety ratings: Figure 6.1.5 shows a main effect of stimulus ($F(2,24) = 26.10$, $p<0.05$), where planned contrasts indicated that there was no significant difference between A and B ($F(1,12) = 1.05$, $p=0.33$), while the difference between A and C was significant ($F(1,12) = 50.43$, $p<0.05$).

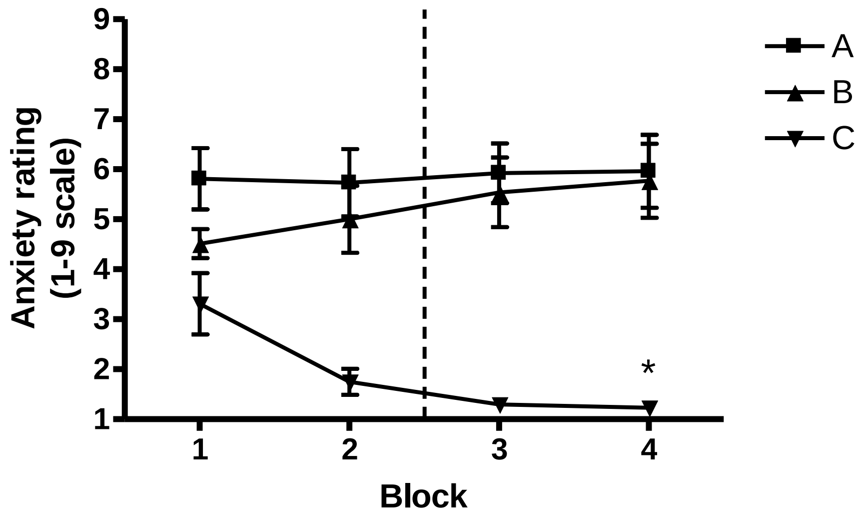
Figure 6.1.5: Anxiety ratings for A, B, and C stimuli measured throughout conditioning, and collapsed across Pavlovian and instrumental phases. Values are mean ± SEM



* = p<0.05 compared to stimulus C

Figure 6.1.6 shows that there was also a stimulus x block interaction ($F(6,72) = 5.17$, $p<0.05$), but planned contrasts revealed no differences. However, there appeared to be a general decrease in anxiety for C and a general increase in anxiety for B, while A did not appear to change over block. Post-hoc t-tests were performed between blocks 1 and 4 for A, B and C. Results indicated that A did not increase over block ($t(12) = 0.23$, $p=0.82$), nor did B ($t(12) = 1.96$, $p=0.74$), but anxiety for C did significantly decrease over block ($t(12) = 3.32$, $p<0.05$).

Figure 6.1.6: Anxiety ratings for A, B and C stimuli measured throughout conditioning, and divided into 4 blocks. The dotted line represents the separation between Pavlovian and instrumental blocks. Values are mean ± SEM

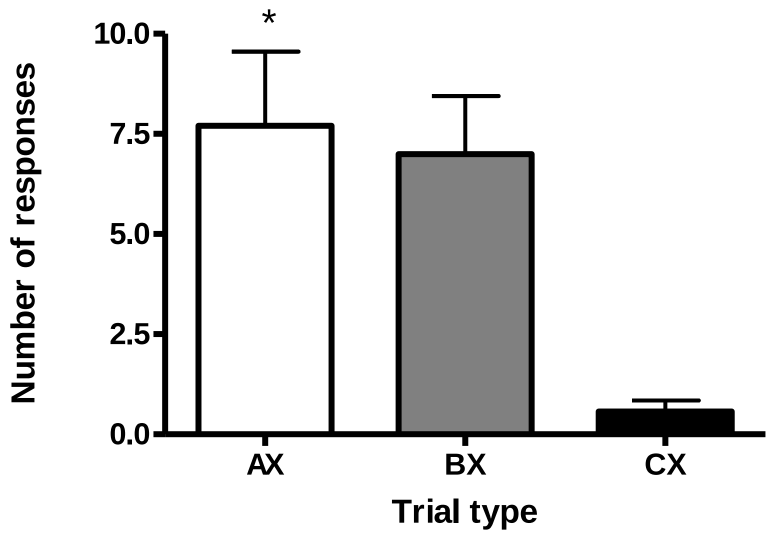


* = p<0.05 post-hoc for C between block 1 and 4

Variables measuring avoidance responses during instrumental conditioning only:

Number of responses: Figure 6.1.7 shows there was a significant main effect of stimulus ($F(2,24) = 16.61$, $p<0.05$), where planned contrasts indicated that there was no difference in the number of responses made in the presence of A than in the presence of B ($F(1,12) = 0.97$, $p=0.35$), but more responses were made in the presence of A than C ($F(1,12) = 16.21$, $p<0.05$).

Figure 6.1.7: Number of avoidance responses made on AX, BX, and CX trials made on a variable interval schedule during the instrumental conditioning phase. Values are mean ± SEM



* = p<0.05 compared to CX trials

Likelihood of a response: There was a significant difference in the number of trials on which a response was made between the CS+ and the CS- ($x2(1) = 180.52$, $p<0.05$), a response was made on 37% of trials when the CS+ was present, while a response was only made on 0.7% of trials when the CS- was present.

Other analyses:

Relationship between attention and conditioned anxiety ratings:

a) Pavlovian phase

There wasn't a significant correlation between anxiety and dwell time bias for A ($r = 0.45$, $p=0.12$).

b) Instrumental phase

There was a borderline significant correlation between anxiety and dwell time bias for A ($r = 0.54$, $p=0.06$).

Relationship between attention and incentive value of the outcome:

Adding the aversive rating for the noise outcome as a covariate in the dwell time bias analysis abolished the main effect of stimulus ($F(2,22) = 1.38$, $p=0.27$) and the stimulus x block interaction ($F(6,66) = 0.97$, $p=0.45$).

Discussion

The addition of an avoidance response to a Pavlovian conditioning paradigm did not appear to alter the control of attentional mechanisms. Throughout conditioning attention was greater for the CS+ over the CS-, while attention for the CS+ and CS+/- was at a similar level. This data appeared to match the pattern of results for anxiety ratings, while adding the incentive rating of the noise outcome as a covariate abolished the dwell time bias for the CS+. Such findings appear to support the incentive value hypothesis of attention that stimuli high in incentive salience are attended to and processed more effectively (Lang et al., 1997). In addition, while the purpose of the current study was not to separate valence (Pratto & John, 1991) and motivational models (Lang et al., 1997) of attention, a comparison of the data in support of these theories will also be discussed.

The introduction of an avoidance response increased attention for the CS+ in accordance with a motivational theory of attention. According to such theories, enhanced attention for an affective stimulus is due to the activation of an appetitive or aversive motivational system (Lang et al., 1997). Hence, the association of the CS+ with an avoidance response should activate the aversive motivational system to a greater extent than a CS+ that was associated with the outcome alone. Such findings appear to contradict those of prior studies where the addition of an avoidance response was related to the reduction in arousal for the CS+ as measured through skin conductance responses (Delgado et al., 2009; Lovibond et al., 2008). As previously noted, skin conductance responses are associated with the orienting response (Lang et al., 1993), so the absence of a decrease in attention in the current study to a CS+ where an avoidance response could be made contradicts the findings of these prior investigations. Moreover, there are several methodological differences that may account for these contrasting reports. Firstly, in the Lovibond et al. study skin conductance response was measured during the entire trial presentation (10 seconds) during which time the conditioned stimulus was present for the first 5 seconds. Thus, the skin conductance response in this paradigm may not necessarily have been related specifically to the CS. In the Delgado et al. study, the skin conductance response was measured as the base-to-peak amplitude only during the presentation of the CS, and consequently the same argument cannot be applied. However, participants had already undergone 11 trials where they received the shock outcome, 6 of which they had received in a row. Thus, it is plausible that the decrease in skin conductance response was related to enhanced habituation effects as a result of the number of consecutive presentations of the outcome. Moreover, there may also be differences in habituation rates for a shock outcome (as used in the Delgado et al study), and the noise outcome used in the present study, which may account for the contrasting data. An alternative explanation for this discrepancy is that in both of the prior studies, only one response was required in order to avoid the noise, while in the present study multiple responses were induced via employment of a variable interval schedule. Schedules of reinforcement encouraging multiple responses may be more likely to enhance attention according to the "mobilization for action" hypotheses of attention (Lang et al., 1997; Lang & Davis, 2006) because they involve sustained responding, and may subsequently activate incentive motivational systems for longer.

However, another interpretation of the data is that attention for the CS+ was related to the affective value of the stimulus, rather than its motivational properties. According to negativity bias theories of attention, attention is mediated by the negative valence of the stimulus (Pratto & John, 1991). While anxiety ratings for the CS+ did not increase concurrently with dwell time biases for the CS+, there was a trend for dwell time biases and anxiety ratings for the CS+ to be positively correlated once the avoidance response had been introduced. One possibility for these discrepant findings is that while subjective anxiety did not change over block, participants became more sensitized to it. Bradley, Cuthbert, & Lang (1996) conducted a study where they obtained a variety of physiological reactions measuring affective and attentional processing of pleasant, unpleasant, and neutral pictures. They found that all physiological responding (eg. heart rate response and skin conductance) was maintained while corrugator electromyographic [EMG] activity (a measure of affective processing) became sensitized over repeated presentations. Thus, the emotionality of the stimuli in the present study may have had a greater influence on attention as conditioning progressed. However, a control group where an avoidance response is not added is required in order to make any further conclusions regarding whether attentional bias was mediated by the motivational or affective salience of the stimuli.

The hypothesis that the introduction of an avoidance response would stimulate error-driven attention was not supported as attention did not decrease to the CS+ once the response was introduced. Furthermore, according to response discrimination data participants were able to learn that the avoidance response was effective in the presence of the CS+ but not in the presence of the CS-, such that the lack of attention to the uncertain stimulus cannot be attributed to a lack of motivation in ascertaining the response contingencies. However, while attention may not have been allocated according to the uncertainty of the stimulus in predicting the outcome, it is possible that attention may have been allocated according to the prediction error associated with whether the response was reinforced or not. Prediction errors associated with Pavlovian and instrumental conditioning may be dissociated - (O'Doherty et al., 2004) found that reward prediction error-related activity was elicited in the ventral striatum during both Pavlovian and instrumental conditioning, while prediction-error activity in the dorsal striatum was only present during instrumental conditioning. In the current study, making a response was effective in cancelling the noise on 50% of CS+ trials and effective on 25% of CS+/- trials, allowing for the possibility that instrumental prediction errors may have become associated with the conditioned stimuli. That said, such a theory only applies if new stimulus-response associations were formed during the instrumental phase as only under these conditions would the conditioned stimulus acquire an increase in associative strength, and consequently attract attention. If cognitive theories of avoidance behaviour are correct, as indeed the majority of evidence supports (Declercq et al., 2008; Lovibond & Shanks, 2002), then the associability of the stimulus should not change with the introduction of the instrumental response, and the increased attention to the CS+ during this phase cannot be attributed to prediction error. While the author favours the cognitive account of avoidance, the absence of any data on participant knowledge of the instrumental response contingencies means that the stimulus-response learning interpretation cannot be completely rejected. However, despite this deficiency in the data, the absence of an attentional bias for the most uncertain stimulus (CS+/-) appears to contradict theories concerning the role of prediction error in decision-making processes (Pessiglione et al., 2006). Indeed, the number of avoidance responses in the current design appeared to indicate that motivated responding was related to the affective value of the outcome, as response rate was the same for both the CS+ and the CS+/-, which matched the anxiety ratings for these stimuli. Such findings implicate the role of affective value in decision-making as well as prediction error. Certainly, the somatic marker hypothesis (Damasio, 1996) postulates that decisions are often based on autonomic responses to stimuli. Thus, in the present study, autonomic responses rather than prediction errors may have been used in guiding motivated responding, foregoing the need for goal-driven mechanisms to bias attention according to the prediction error. That said, the comparison of cognitive and somatic theories of decision-making are outside the scope of the current study; further investigations are required to establish the mechanisms through which avoidance behaviours are controlled.

In addition to these future areas of investigation, there was one further limitation in the current study that needs to be addressed. The extensive Pavlovian training may have activated incentive-driven mechanisms of attention to such an extent that attention for prediction error was masked in the subsequent instrumental phase. As discussed in the introduction, the purpose of the Pavlovian training was to ensure that the appropriate conditioned affective response developed. However, in the absence of such a prolonged training period, prediction-error mechanisms of attention may be able to override this affective bias. A replication of the present study but without the initial Pavlovian training period would help clarify the conditions under which incentive-driven mechanisms and prediction-error mechanisms of attention may dominate.

7. General Discussion

7.1 Summary of findings

In chapter one, I reviewed the literature on attention for unconditioned incentive stimuli and for conditioned stimuli predictive of rewarding or aversive outcomes, and I suggested that attention would be mediated by the acquired incentive properties of such stimuli, rather than the associated prediction error. I proposed to investigate this hypothesis by using a classical conditioning procedure in which the occurrence of an appetitive or an aversive outcome was predicted, with varying probabilities, by visual stimuli. I predicted that attention for conditioned stimuli, regardless of the valence of the outcome, would be greater for the CS+ over both a partial predictor (CS+/-) and a non-predictor of the outcome (CS-), even after learning of the contingencies had occurred.

In experiment 2.1, described in chapter two, I set out to acquire various measures of incentive value for appetitive and aversive outcomes for use in subsequent experiments. Participants underwent a variable-interval procedure in which a visual stimulus signalled that they should make a response in order to receive a reward (5p, 10p, or 50p) or to avoid a noise (92db, 97db, 102db). Schedules for each reinforcer were in separate blocks, and ended with participants providing subjective ratings of emotional and motivational properties of the reinforcer. Behavioural results indicated that low, medium and high levels of reinforcer value were matched in incentive value between valence categories. While there was some indication of differences in behavioural strategies dependent on whether the outcome was aversive or appetitive, subjective motivational and affective ratings of the reinforcer also appeared to match behavioural responses. As such, the behavioural measures were considered to be a fairly accurate representation of incentive value of the outcome. In addition, subjective ratings of the affective properties indicated a separation within valence categories between the medium and high intensity outcomes. I concluded that subsequent experiments should use the 97db and 10p values of reinforcer as they were matched according to behavioural and subjective ratings of incentive value. Thus, experiments using these stimuli were less likely to be confounded by differences in incentive level. Although 102db and 50p may also have been a viable option, 97db had been successfully used in a previous conditioning study.

In experiment 3.1, described in chapter 3, I aimed to investigate the mechanisms of attention for conditioned affective stimuli. I employed a discriminative conditioning procedure using arbitrary computer-presented stimuli as conditioned stimuli, and either 10p or 97db as the unconditioned stimulus. Conditioned stimuli were presented as part of a pair with a context stimulus (X) and were fully predictive (CS+), partially predictive (CS+/-) or non-predictive (CS-) of the outcome. Initially, participants underwent a discriminative procedure where only emotional ratings of the conditioned stimuli were measured. This was in order to elicit emotional conditioning, and in conjunction with a measure of emotionality obtained post-declarative conditioning, was employed to provide a more accurate measure of the change of emotionality as learning progressed. Participants subsequently completed a declarative conditioning phase where only expectancy ratings and attention were measured. All participants who became aware of the stimulus contingencies reported an appropriate learning and emotional discrimination between the CS+ and the CS-. According to the dwell time measure of attention, regardless of whether the outcome was 10p or 97db, attention was greatest for the partial predictor (CS+/-), supporting the prediction-error hypothesis of attention, rather than the affective hypothesis of attention. However, the ability of the participants to control the length of the attentional time window through making an expectancy response may have created a bias in the data towards the most uncertain predictor.

In experiment 4.1, described in chapter 4, I set out to eliminate confounds from the experiment 3.1, and continued to explore whether attention is mediated by prediction error, or by incentive value. Participants again underwent a discriminative conditioning procedure but with several improvements in order to eliminate some of the confounds from the previous study. Such improvements included a fixed stimulus presentation in order to eliminate the confound of the participant being able to control the duration of the stimulus presentation, while a delay was added between the conditioned and unconditioned stimuli in order to ensure that attention was driven by processes arising from Pavlovian associations. In addition, two higher levels of the outcomes were used (102db and 50p) in order to ensure that stimuli were of a high enough incentive value to induce incentive-driven mechanisms of attention. These stimuli were selected on the basis that they had greater affective and motivational properties than the 97db and 10p stimuli, according to findings reported in experiment 2.1. Contrary to the previous study, attention appeared to match the affective value of the stimuli for the noise conditions (CS+>CS+/->CS-). While there was no significant difference in attention between 102db and 97db stimuli there were trends suggestive of an increased bias for the CS+ in the 102db condition. In contrast, for the money conditions attention was greater for the partial predictor (CS+/-) while neither the CS+ or CS- appeared to yield an attentional bias. Expectancy ratings indicated that learning was not delayed for the noise conditions relative to the money conditions, so a slower rate of learning cannot account for these differences. Likewise, emotional conditioning had occurred for both money conditions, indicating that a deficit in the conditioned affective response could not account for the lack of an attentional bias to the CS+. Thus, attention for aversive and appetitive conditioned stimuli appeared to be mediated by qualitatively different mechanisms – attention for conditioned rewards were error-driven, while attention for conditioned aversive events were determined by the incentive value of the stimulus. However, it was acknowledged that rewards may have to be of a higher incentive value in order to elicit incentive-driven mechanisms of attention.

The purpose of experiment 5.1, described in chapter 5, was to investigate mechanisms of attention for stimuli predictive of a drug outcome. Experiment 4.1 had demonstrated that when a monetary outcome served as the appetitive unconditioned stimulus, attention was greatest for the partial predictor. However, monetary stimuli may have low motivational salience, while cigarette stimuli for nicotine-deprived smokers may have a higher motivational salience needed to induce incentive-driven mechanisms of attention. The hypothesis that attention for drug cues would be mediated by the appetitive properties associated with the drug was tested through examining attention and subjective emotional responses during a Pavlovian discriminative conditioning procedure, when the outcome was ¼ cigarette. Dwell time biases were of the order of magnitude CS+>CS+/->CS-, which matched the conditioned affective response according to emotional ratings. Prediction error theories of attention were not supported as there was no evidence of an attentional bias for the CS+/-, or a decrease in attention for the CS+. Although it is unclear whether the cigarette stimuli induced incentive-driven mechanisms of attention via their affective or motivational properties, I concluded that stimuli predictive of drug rewards are attended to according to their incentive properties.

The results from experiment 4.1 indicated that attention for the aversive noise outcomes was mediated by their incentive properties. However, it was not known whether such an effect would occur in an instrumental avoidance paradigm. Prediction errors may have more of a role in attention for stimuli predictive of an instrumental response. As knowledge of the probability of an outcome occurring is important in guiding instrumental responding, attention may become guided by the prediction error. According to cognitive theories of avoidance responding (Lovibond et al., 2008), the avoidance response is elicited by an explicit expectancy of the outcome. Thus, it is plausible that in avoidance learning attention is mediated by the uncertainty of the stimuli in predicting an outcome, as this would aid in the decision-making process of whether or not to make an avoidance response. The purpose of experiment 6.1, described in chapter 6, was to test this hypothesis by adding additional trials to a Pavlovian discriminative procedure, whereby the conditioned stimuli signalled that an avoidance response could be made. For this procedure the 102db noise was used as the unconditioned stimulus as the behavioural responding data from experiment 4.1 indicated that it may have a higher incentive value that the 97db noise. This would increase the likelihood that participants would be motivated to avoid the outcome. Results indicated that attention during the Pavlovian training phase matched the findings from experiment 4.1, where both attention and affective value were of the magnitude CS>CS+/->CS-. The addition of the avoidance response did not decrease attention to the CS+, in fact attention increased to the CS+ with the introduction of the avoidance response. I concluded that the introduction of the avoidance response probably increased the motivational salience of the

CS+, leading to an increase in attentional bias. However, I also acknowledged that in the absence of a control group where no instrumental avoidance response was added, it remained unclear whether this increase was related to increases in the affective or the motivational properties of the stimuli.

In summary, the conditioned incentive properties of the stimuli did mediate attentional biases for stimuli predictive of both appetitive and aversive outcomes. However, this effect was more robust for aversive outcomes than for appetitive outcomes. Under conditions where the participant could control the duration of the initial time window in which the stimulus was presented, attention appeared to adhere to prediction error rules regardless of the valence of the outcome, whilst under conditions where stimulus duration was fixed, attention was mediated by the affective value of the outcome for the noise conditions, but not for the money conditions. Attention to aversive outcomes appeared to be mediated by the incentive properties of the stimulus during both Pavlovian and instrumental conditioning. In contrast, for the rewarding monetary outcomes attention was mediated by the uncertainty of the relationship between the CS and the outcome. It was only when a different rewarding outcome was used (cigarettes) that attention was driven by the incentive properties of the conditioned stimuli. The discussion will begin with an attempt to clarify the conditions under which attention may be driven by the prediction error and the conditions under which attention is driven by the incentive salience, for both types of outcome. Furthermore, the possibility of differences in sensitivity to arousal for aversive and appetitive outcomes will be addressed. Potential problems with the methodologies in the experiments reported, as well as suggestions for future research and implications of this research will end the discussion.

7.2 Conditions facilitating incentive mechanisms of attention

An overview of the findings indicated that dependent upon certain conditions, attention may be driven by the prediction error or by the incentive properties associated with a stimulus. This effect was present, to some extent, for both aversive and appetitive outcomes. Thus, there was support for both prediction error (Pearce & Hall, 1980) and incentive (Bindra, 1969; Lang et al., 1993) theories of attention. In experiment 4.1 the monetary outcomes appeared to adhere to prediction-error mechanisms of attention as attention was highest for the partial predictor, while there was no attentional bias for either the CS+ or the CS-. However, when the incentive salience of the outcome was increased by using cigarette outcomes for a group of nicotine-deprived smokers attention appeared to be mediated by this incentive value, rather than by the predictive uncertainty associated with the conditioned stimuli. Likewise, there was evidence of a switch in attention from error to incentive mechanisms when the aversiveness level of the noise stimuli was increased in experiment 4.1. Although it did not become significant, a trend in the mean values indicated that attention was highest for the partial predictor in the 97 db condition, while attention was greatest for the CS+ for the 102 db outcome. Collectively, these findings suggest that attention may be mediated by prediction error regardless of the valence of the outcome, but that at a certain level of incentive salience, attention becomes dominated by the incentive value of the stimulus. Although caution must be exerted regarding this hypothesis for aversive outcomes (due to the lack of a significant effect), the existence of such a balance between mechanisms in attention would explain some of the discrepancies in the literature. It explains how Hogarth et al. (2008) who used a similar design, and Kaye and Pearce (1984) could report that attention decreased for a stimulus predictive of an aversive and a rewarding outcome respectively, while attention was maintained for a partial predictor. In the Hogarth et al (2008) study a 97db noise was used, which may not have been salient enough to induce incentive-driven mechanisms of attention. Likewise, in the Kaye and Pearce (1984) study the food stimuli may not have possessed sufficient incentive salience to dominate error-driven mechanisms, although as this study used rats and measured orienting responses through rearing responses, this may also account for the discrepancy with the data in experiment 5.1. This would also account for the discrepancy between the findings of such conditioning studies and the large body of literature where attentional biases have been reported for highly salient stimuli. Such examples include drug-related stimuli (Gross et al., 1993; Lubman et al., 2000; Rosse et al., 1997), and threatening stimuli (Carretie, Mercado, Tapia, & Hinojosa, 2001; Hansen & Hansen, 1988; Ohman et al., 2001; Pratto & John, 1991) - particularly for high trait anxiety individuals (E. Fox et al., 2001a; E. H. Koster et al., 2006). It may be the case that when a stimulus becomes associated with a salient outcome, the appetitive or aversive properties associated with the outcome will only dominate error-driven mechanisms when the outcome attains a certain threshold of incentive salience.

7.3. Conditions facilitating error-driven mechanisms

While increasing the incentive salience of the outcome also appeared to increase the likelihood that attention for a CS would be mediated by its acquired affective-motivational properties, other aspects of the data appeared to indicate that certain alternative conditions would promote error-driven mechanisms of attention. The results described in chapter 3 gave some indication that incentive mechanisms may be overcome when goal-driven mechanisms are biased towards prediction error. During this procedure participants had the ability to control the duration of the time window in which attention was measured via making an expectancy response. This ability may have biased attention towards goal-directed processes related to stimulus uncertainty as has previously been reported (L. Hogarth et al., 2009). In contrast, when participants are able to control the duration of stimulus presentation but do not have to make a response based on knowledge of the predictive certainty (such as an expectancy response), attention may continue to be driven by the incentive value. For example, (Moratti, Keil, & Stolarova, 2004) reported that participants chose to view highly arousing affective images for longer than low arousal images when they could control the viewing time. Clearly, in this scenario, no ratings relating to stimulus contingencies were obtained as the pictures were not predictive of an outcome. The possibility was subsequently inferred that attention may become biased towards prediction error associations, under conditions where there is an additional motivation to learn about the stimulus contingencies. That is, when there is an additional motivation to acquire knowledge of the outcome contingencies, attention may become biased towards stimuli according to their predictive uncertainty. Indeed, there was some evidence that prediction errors may be associated with decision-making processes such as those involved in making an instrumental response (Pessiglione et al., 2006). An attempt was made in experiment 6.1 to increase the motivation to attend to the predictive uncertainty of the stimuli for an aversive outcome to test the hypothesis that under certain conditions aversive stimuli may also elicit error-driven attention. Cognitive theories of instrumental conditioning state that action selection is based on the expectancy of an outcome elicited by the conditioned stimulus (Lovibond et al., 2008), indicating that it was possible that attention to predictive uncertainty may occur in order to aid decisions in making avoidance responses. Thus, an attempt was made to induce error-driven attention for an aversive stimulus through the introduction of an avoidance response in the presence of the CS+ in experiment 6.1. However, even under such conditions attention did not become biased towards the most uncertain predictor. One reason for this finding may be that action selection processes for aversive stimuli are mediated by non-cognitive processes, as proposed by the somatic-marker hypothesis (Damasio, 1996), and therefore increased attention to an uncertain predictor should not be elicited. Secondly, the introduction of the avoidance response may have imbibed the CS+ with an even greater incentive salience in accordance with theories that attentional biases may also be related to mobilization for action (Lang et al., 1997; Lang & Davis, 2006). A final hypothesis concerns a methodological confound of the study. The prolonged Pavlovian conditioning trials, which occurred prior to the introduction of the instrumental response, may have biased attention to the emotional qualities of the CS+ to such an extent that it was impossible to override it, even when conditions favoured error-driven mechanisms. Nevertheless, the current investigation has established that attention for a stimulus predictive of an aversive outcome may be mediated by the associated incentive properties in a variety of learning contexts.

7.4 Mechanisms of attention for uncertainty and incentive salience

Thus far, the findings indicate that under certain conditions attention may be biased towards the incentive properties of a conditioned stimulus, and under other conditions it may be mediated by stimulus uncertainty. However, to what extent these mechanisms of attention are independent is unclear. Indeed, the findings of one investigation indicated that uncertainty and arousal (related to the incentive properties of a stimulus) may be processed separately in areas associated with attention, but that they may also be integrated together in other regions associated with attention (Critchley, Mathias, & Dolan, 2001). In the Critchley et al. (2001) study, participants' brain activity was measured during a time-window between making a reward-related decision and receiving an outcome (win or loss); the more uncertain the outcome the greater the activity in the anterior cingulate and orbitofrontal cortex, while anticipatory arousal (as measured through GSR) was related to increased activity in the dorsolateral prefrontal cortex, parietal cortices, and the anterior cingulate. Both the dorsolateral prefrontal cortex and the anterior cingulate are associated with the attentional network (Nobre et al., 1997). Thus, the differential activation of these regions for uncertainty and arousal imply that arousal and uncertainty mechanisms of attention may be mediated independently. However, in the Critchley et al. study a discrete region of the anterior cingulate was activated by both arousal and uncertainty, signifying that arousal and uncertainty may also be integrated together in influencing attention. In fact, the anterior cingulate has already been proposed as the site where motivationally-significant information (including prediction errors) may be integrated with physiological arousal to initiate appropriate responses (Critchley, Corfield, Chandler, Mathias, & Dolan, 2000). In relation to the current findings, it is plausible that the overt measure of attention reflects a combination of the error-term and the incentive value of the stimulus. Certainly, some models of incentive salience state that the arousal elicited by incentive stimuli is related to sustained attention (to aid in encoding processes) rather than the initial capture of attention (Van Strien, Langeslag, Strekalova, Gootjes, & Franken, 2009). In contrast, Pearce and Hall (1980) postulate that stimuli associated with low prediction errors may capture attention, but subsequently are not attended to. Consequently, it is plausible that prediction error processes mediate the initial capture of attention for stimuli, and only when the incentive value for the outcome is high will attention subsequently be maintained for these stimuli. Indeed, when attention appeared to be determined by the incentive value (eg. for noise outcomes in experiments 4.1 and 6.1, and for the cigarette outcome in experiment 5.1) the dwell time bias for the partial predictor may have reflected a combination of the high prediction error and the incentive value. That is, dwell time biases for partial predictors of a high incentive outcome may reflect the summation of attention mediated by stimulus uncertainty and attention mediated by the incentive properties. Differences between the CS+ and CS+/- in these three aforementioned experiments also did not reach statistical significance, providing further support for the hypothesis that attention may reflect a combination of uncertainty and incentive salience. Clearly, the exact nature of the integration between these two mechanisms requires further investigation.

7.5 Differences in aversive and appetitive attention

An interesting finding from the series of investigations was the indication that attentional mechanisms for conditioned aversive stimuli are more sensitive to the incentive properties of the outcome than attentional mechanisms for appetitive stimuli. That is, aversive stimuli will attract attention at lower levels of incentive salience than rewarding stimuli of an equivalent level of incentive salience. Even though the monetary and noise outcomes were matched in experiment 2.1 according to incentive salience levels, in experiment 4.1 only the noise outcomes demonstrated that attention was mediated by the incentive properties of that stimulus. In contrast, attention continued to be mediated by prediction error for both high and low money outcomes. In addition, GSR measures of arousal (used to provide a measure of the conditioned incentive salience of the stimuli) indicated that conditioned stimuli for the appetitive and aversive outcomes elicited an equivalent level of conditioned arousal. Such findings concur with the theory that arousal for aversive and appetitive outcomes may be mediated by different mechanisms (Berntson et al., 2007). From an evolutionary perspective, the arousing properties of an aversive stimulus may have more significance for an organism than the arousing properties of an appetitive stimulus. That is, it may be more important to survival to be immediately aware of, and make fast responses to, stimuli signalling the imminence of an aversive outcome rather than stimuli signalling a rewarding event (G. P. McNally & Westbrook, 2006). Thus, arousal may have a greater role in attention for aversive stimuli than for appetitive stimuli, as the increase in autonomic arousal may be particularly useful for initiating "fight-or-flight" responses (Lang & Davis, 2006).

7.6 General methodological concerns

One major methodological concern is that the paradigm may not have reflected learning in a naturalistic setting. The expectancy question presented after every trial may have biased goal-directed attentional processes in order to answer the question. Indeed, a variety of studies have reported that when participants are required to consciously evaluate stimuli attentional biases are different compared to when passively viewing stimuli. For example, when affective stimuli were presented as targets they induced increased late positive potential (LPP) amplitudes (an EEG component associated with attention) in centro-parietal areas, relative to when they were presented as non-targets (Ferrari et al., 2008). In fact, the effect of the affective value of the stimuli (emotional vs. non-emotional) and the task-relevance (target vs. non-target) had an additive effect on the LPP amplitude. The same may apply, therefore, for error-driven mechanisms when the purpose of the task is to report stimulus contingencies. While this may have had some relevance for the money conditions in experiment 4.1, the fact that both noise conditions in this same study, and cigarette outcomes in experiment 5.1 did not exhibit error-driven attentional biases indicates that the expectancy question was not a significant confound in the current investigations. Likewise, it is also possible that the emotional questions may have biased attention towards the emotional qualities of the stimuli. However, these questions were only given at the end of every 36 trials in experiment 4.1 and 6.1, and at the end of every 24 trials in experiment 5.1. In addition, Codispoti, Ferrari, & Bradley (2007) reported that in a study where viewing was passive, emotional stimuli (pleasant and unpleasant) induced greater attention as measured by enhanced early and late ERP amplitudes in occipitotemporal and centroparietal regions, compared to non-emotional stimuli. Thus, even in the absence of the emotional questions, attention can be mediated by the incentive properties. Certainly, the finding that even under conditions where attention was more likely to have been biased towards prediction error mechanisms (through expectancy questions on every trial), attention was still biased towards the incentive value of the stimulus (experiments 4.1, 5.1 and 6.1) is evidence for the stability of incentive-driven mechanisms.

Another issue, related to interpreting the attentional data as supporting error-driven mechanisms in experiment 3.1 and 4.1, is that the partial predictor may not have been a truly “uncertain” stimulus. That is, participants may have learnt that the partial predictor was a redundant predictor of the outcome as it did not reliably predict reward or punishment. However, why participants would have preferentially attended to this stimulus in experiments 3.1 (money and noise conditions) and 4.1 (money conditions only), in the knowledge that it was redundant, is not supported by any learning theory of attention. Indeed, some theories of learning state that a redundant stimulus will be learned to be ignored (Kruschke & Blair, 2000). Frustration induced by the partial predictor does also not account for this bias as there was no relationship between anxiety ratings and attention for the CS+/- for the money conditions in experiment 4.1. While it is acknowledged that ratings of "anxiety" do not necessarily reflect "frustration" (even though both may be conceptualised as negative affective states) it is likely that they reflect similar processes. Indeed, in a study on temperament and using factor analysis (Derryberry & Rothbart, 1988) reported that "frustration" was closely correlated with other negative affective states such as "fear", with both being related in the same manner to factors of arousal and attention. Thus, it is unlikely that in the current study the attentional biases for the partial predictor were mediated by frustration.

7.7 Implications

The strongest implication in the current study is that cues predictive of a highly motivating appetitive or aversive outcome have the ability to attract and hold attention. In the context of addiction this may provide a possible pathway for relapse in addiction in accordance with incentive salience (Robinson & Berridge, 1993) and hedonic affective (Stewart et al., 1984) theories of addiction. The associated incentive properties of the conditioned stimulus may engage attention, leading to increased craving and drug-seeking behaviours. Field & Eastwood (2005) reported that attentional biases to alcohol stimuli increased both craving and drug-seeking responses in heavy social drinkers, while increasing attention to cigarette stimuli has also been shown to elicit increased urges to smoke in smokers (Attwood et al., 2008). The present investigation added additional support to this possible relapse mechanism by using conditioned stimuli, and demonstrating that attention did not diminish to such stimuli as learning progressed. In a similar vein, the current data support the employment of interventions in the treatment of anxiety disorders, where the distraction of attention away from threatening stimuli has been implicated as a possible treatment (C. MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002a). As in the addiction literature, there are reports that directing attention towards a threatening stimulus may increase the vulnerability to engage in maladaptive behaviours. For example, directing attention towards negative words increased the likelihood that participants would develop a negative emotional state in response to a stress task (C. MacLeod et al., 2002b). The present findings also provide additional support for the model of attentional biases in the maintenance of anxiety disorders (Mathews & Mackintosh, 1998; Rapee & Heimberg, 1997) - the aversive properties of conditioned stimuli capture attention, and consequently, even in the absence of the threat itself, stimuli associated with its occurrence could trigger anxiety responses. Furthermore, differences identified in the present series of experiments regarding the ability of aversive and appetitive stimuli to elicit incentive-driven attention may also add to the development of treatment strategies. The different contexts under which appetitive and aversive stimuli are able to induce incentive-driven attention may guide interventions in a more precise way.

7.8 Future directions

While the present findings indicate that attentional biases for conditioned stimuli may reflect the emotional significance of that stimuli and support the maintenance of drug addictions and anxiety disorders, further investigations are required in order to ascertain the applicability of the results from the present study on these pathological disorders.

A major problem with making inferences with the current data is that attention may not be mediated in the same way for individuals with pathological anxiety disorders or drug addictions. Indeed, some theories concerning the role of attention in anxiety state that in some anxiety disorders individuals will avoid threat stimuli, and this may prevent habituation and emotional processing to the threat, while this is not the case in non-clinical populations (Mogg et al., 1987). However, support for this theory is mixed with some studies reporting vigilance for threat cues in high trait anxiety individuals (Mogg, Bradley et al., 2004), and others reporting avoidance for threat cues in high trait anxiety individuals (E. H. Koster et al., 2006). The conditions under which attentional avoidance occurs requires further investigation as this clearly has implications for the use of attentional distraction procedures in interventions for anxiety disorders. Likewise, when a drug outcome is used, it is unclear whether participants with particularly high nicotine-dependence would be as influenced by the incentive value of the cues as those who were moderately nicotine-dependent. Indeed, it has been reported in the literature that highly dependent individuals may be governed by mechanisms of habit and become less reactive to the incentive value of drug cues (Rehme et al., 2009), implying that the incentive properties of drug cues may no longer capture attention. The application of attention-based interventions to different populations of drug-users also requires exploration.

A second direction, equally relevant, is the impact of these attentional biases on behaviour. Some studies have reported that while conditioned stimuli may elicit attentional biases, these attentional biases are not required for instrumental responding to gain a reward. For example, Hogarth, Dickinson, Janowski, Nikitina, & Duka (2008) reported that when a dual-task was included in an instrumental conditioning paradigm, attentional bias was abolished for an S+ predictive of cigarette reward, while instrumental responding to obtain the cigarette was not abolished. Such findings imply that the abolition of attentional biases to conditioned stimuli would not subsequently abolish drug-seeking behaviour. However, it is also well reported in the literature that the affective-motivational value of Pavlovian cues may invigorate instrumental responding, which is known as the Pavlovian-to-instrumental transfer (PIT) effect. In these paradigms Pavlovian and instrumental conditioning occur in separate phases, and then a subsequent phase is introduced where an instrumental response can be made in the presence of the conditioned stimulus. Particularly in the animal literature, the presence of the Pavlovian cues in this final phase has been shown to increase instrumental responding to obtain the reward (Crombag, Galarce, & Holland, 2008; Glasner et al., 2005), while there is also evidence of this effect in humans using monetary outcomes (Talmi, Seymour, Dayan, & Dolan, 2008). In contrast, there have been fewer investigations on aversive PIT, although there is evidence that Pavlovian cues previously associated with foot-shock reduce instrumental responding for a reward (George, Hutson, & Stephens, 2009), indicating that the aversive affective properties of the conditioned stimulus are able to influence instrumental responding. The Pavlovian-to-instrumental transfer effect is clearly a mechanism through which both the appetitive and aversive properties of an incentive cue may come to influence behaviours such as drug-seeking and threat avoidance. The role of attentional biases in these effects may well be a fruitful avenue of investigation.

Finally, the cognitive impact of conditioned incentive stimuli needs to be investigated. This is particularly important in relation to the ability to access coping mechanisms in anxiety and addictions. The presence of such stimuli may take up cognitive resources to the extent that individuals are unable to process other relevant information, and this may also play a role in prolonging such disorders. Futhermore, the impairment in the disengagement component of attention, particularly recognised for aversive stimuli (E. H. Koster et al., 2006), may impact on the ability to attend to, and hence process, alternative more adaptive information. Dual-task paradigms would be useful in clarifying these issues as they should demonstrate the capacity of these conditioned stimuli in disrupting ongoing cognitive activities, and the extent to which disengagement may be impaired.

7.9 Concluding remarks

In this thesis, the mechanisms underlying attention to conditioned incentive stimuli were considered. I suggested that attention for stimuli predictive of a rewarding or an aversive outcome would be driven by the incentive salience properties of the stimulus rather than by predictive uncertainty, although it was also acknowledged that under certain conditions error-driven attention may be more likely to occur. Using classical conditioning procedures I demonstrated that when an outcome was high enough in incentive value, attention would be mediated by the incentive properties of the stimulus. For rewarding outcomes this effect was present when cigarette stimuli were used but not for monetary outcomes, while incentive-driven mechanisms appeared to drive attention for a highly aversive noise even under conditions facilitating error-driven mechanisms. Monetary outcomes appeared to be driven by the uncertainty of the stimulus as attention was greatest for the partial predictor over a full predictor, despite the presence of appropriate emotional conditioning. There was also an indication that attention for the low noise outcome may have been mediated by uncertainty, although this effect was not as robust. These results demonstrate that while both uncertainty and incentive salience may mediate attention, if the acquired incentive properties of a conditioned stimulus are above a certain threshold level attention will be dominated by the these properties, although this threshold level may differ for aversive and appetitive outcomes.

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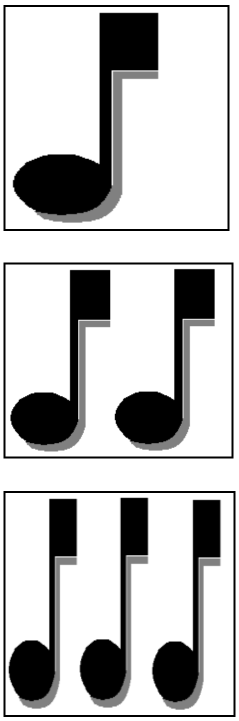
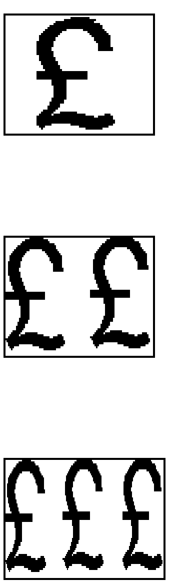
Appendix 1 (experiment 2.1)

a) Visual stimuli used for the noise variable interval schedules

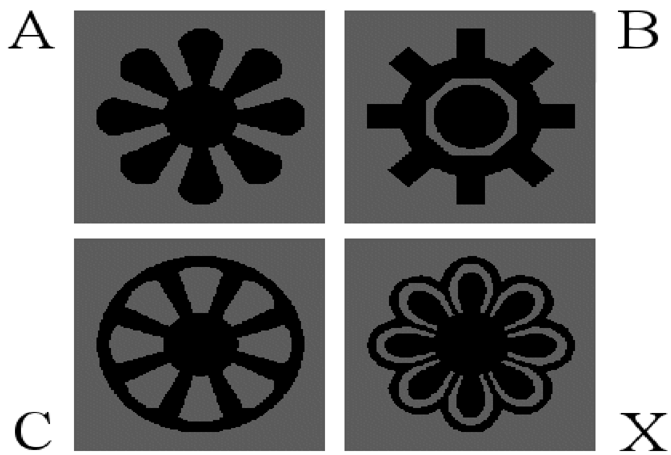


b) Visual stimuli used for the money variable interval schedules



Appendix 2 (experiment 3.1)

Visual stimuli used for the conditioned stimuli. A,B, C, and X were counterbalanced in their role as CS+, CS+/-, CS-, and X.



Questionnaire data for unaware participants taken prior to Pavlovian conditioning. Values are mean ± SEM

Age	Anxiety	Depression	BIS	BAS
20.50 ± 0.50	0.22 ± 0.11	0.20 ± 0.13	2.86 ± 0.44	3.20 ± 0.20

Attentional data for unaware participants on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

Measure	AX	BX	CX
Dwell time bias (first time window, log ten seconds)	-0.01 ± 0.16	0.21 ± 0.11	0.10 ± 0.05
Dwell time bias (second time window, log ten seconds)	0.71 ± 0.35	0.29 ± 0.16	1.01 ± 0.54
Likelihood to first fixation (ratio)	0.01 ± 0.07	0.25 ± 0.26	0.16 ± 0.20

Expectancy ratings for unaware participants on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
6.20 ± 0.39	4.94 ± 0.48	5.01 ± 0.53

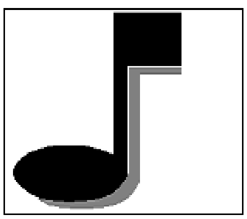
Pleasantness ratings for unaware participants for A, B and C stimuli, collapsed across trials. Values are mean ± SEM

A	B	C
5.25 ± 2.25	6.25 ±0.75	5.25 ± 1.75

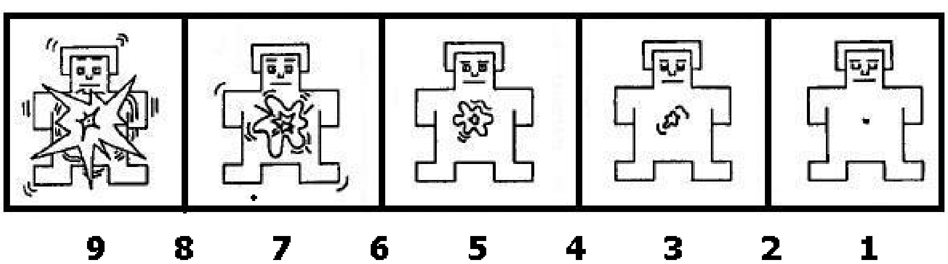
Appendix 3 (experiment 4.1)

Visual stimulus used in the variable interval schedule for the monetary outcomes

Visual stimulus used in the variable interval schedule for the noise outcomes



Visual analogue scale used to measure subjective arousal for A, B, and C stimuli



Questionnaire variables for unaware participants. Values are mean ± SEM

	97db	**10p**	**50p**
Age	19.33 ± 0.88 18-21	20.80 ± 1.85 18-28	20.25 ± 1.11 18-23
BIS	3.62 ± 0.31 3.00-4.00	3.20 ± 0.19 2.71-3.71	2.54 ± 0.40 1.43-3.29
BAS	2.98 ± 0.11 2.77-3.13	3.19 ± 0.18 2.77-3.68	3.11 ± 0.50 3.00-3.22
Anxiety	1.70 ± 0.49) 1.11-2.67	1.27 ± 0.42) -0.33-2.00	0.17 ± 0.22 -0.22-0.78
Depression	1.07 ± 0.43 0.60-1.93	1.32 ± 0.37 0.20-2.00	0.32 ± 0.21 0.00-0.87

Dwell time bias scores for unaware participants on AX, BX, and CX trials, collapsed into two blocks, measured during conditioning. Values are mean ± SEM

	97db	**10p**	**50p**
AX1	-0.13 ± 0.18	0.07 ± 0.12	-0.09 ± 0.07
AX2	-0.19 ± 0.09	0.03 ± 0.17	0.10 ± 0.06
BX1	0.36 ± 0.38	0.38 ± 0.23	-0.10 ± 0.07
BX2	-0.02 ± 0.30	-0.03 ± 0.17	0.04 ± 0.04
CX1	-0.20 ± 0.02	0.02 ± 0.12	0.14 ± 0.10
CX2	-0.09 ± 0.19	0.09 ± 0.08	-0.12 ± 0.11

Expectancy ratings for unaware participants on AX, BX, and CX trials, collapsed into two blocks, measured during conditioning. Values are mean ± SEM

	97db	**10p**	**50p**
AX1	4.96 ± 0.20	5.55 ± 0.46	5.21 ± 0.14
AX2	5.90 ± 0.44	5.89 ± 0.50	5.31 ± 0.28
BX1	5.94 ± 0.34	5.94 ± 0.49	5.52 ± 0.48
BX2	5.71 ± 0.34	6.01 ± 0.30	5.41 ± 0.20
CX1	5.15 ± 0.19	5.60 ± 0.37	5.11 ± 0.30
CX2	4.07 ± 0.37	6.30 ± 0.46	5.51 ± 0.24

Anxiety ratings (97db only) for unaware participants, for A, B, and C stimuli, obtained over conditioning, separated into two blocks. Values are mean ± SEM

A1	3.83 ± 1.42
A2	6.00 ± 0.87
B1	3.65 ± 1.30
B2	5.33 ± 0.83
C1	5.83 ± 1.17
C2	5.02 ± 0.26

Pleasantness ratings for unaware participants, for A, B, and C stimuli, obtained over conditioning, separated into two blocks, presented separately for 10p and 50p conditions. Values are mean ± SEM

	10p	50p
A1	6.80 ± 0.49	6.50 ± 0.79
A2	6.80 ± 0.73	7.14 ± 0.43
B1	6.68 ± 0.95	5.88 ± 1.03
B2	6.30 ± 1.16	5.38 ± 1.16
C1	6.90 ± 0.80	5.88 ± 0.80
C2	8.20 ± 0.20	5.75 ± 0.60

Number of responses for unaware participants made on the variable interval schedules, collapsed over ten intervals, presented separately for each condition

97db	10p	50p
4.73 ± 1.90	3.00 ± 1.01	5.86 ± 1.66

Skin conductance responses for unaware participants and AX, BX, and CX trials, collapsed across trials, presented separately for each condition. Responses are the base-to-peak amplitude and measured in useimens. Values are mean ± SEM

	97db	**10p**	**50p**
AX	1.42 ± 0.73	2.05 ± 0.61	0.95 ± 0.17
BX	0.87 ± 0.30	1.53 ± 0.55	1.18 ± 0.37
CX	1.52 ± 0.42	0.94 ± 0.28	1.16 ± 0.23

Subjective arousal ratings for unaware participants for A, B, and C stimuli, obtained post-conditioning, presented separately for each condition. Responses were made on a 1-9 visual analogue scale. Values are mean ± SEM

	97db	10p	50p
A	6.33 ± 0.67	5.84 ± 0.48	5.50 ± 0.65
B	6.00 ± 1.53	4.40 ± 1.17	4.75 ± 1.25
C	4.67 ± 0.33	3.40 ± 1.17	5.00 ± 0.71

Affective value ratings of the outcome for unaware participants, obtained prior to conditioning, presented separately for each condition. Responses were on a 1-9 Likert scale. Values are mean ± SEM

97db	10p	50p
5.00 ± 1.15	6.00 ± 0.89	8.16 ± 0.28

Appendix 4 (experiment 5.1)

Likelihood to first fixation in aware participants for predictive stimuli (A, B, or C) on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
0.13 ± 0.05	0.06 ± 0.05	0.04 ± 0.06

Dwell time bias scores for unaware participants on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
0.46 ± 0.63	0.69 ± 0.58	0.48 ± 0.27

Likelihood to first fixation for unaware participants for predictive stimuli (A, B, or C) on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
0.22 ± 0.16	0.10 ± 0.08	0.16 ± 0.08

Expectancy ratings for unaware participants on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
5.00 ± 0.74	5.21 ± 0.75	5.56 ± 0.48

Pleasantness ratings for unaware participants for A, B, and C stimuli, collapsed across conditioning trials. Values are mean ± SEM

A	B	C
2.72 ± 0.92	2.89 ± 1.22	3.11 ± 1.49

Affective value rating of the cigarette outcome for unaware participants, obtained prior to conditioning on a 1-9 Likert scale. Values are mean ± SEM

8.67 ± 0.33

Questionnaire variables for unaware participants obtained prior to conditioning. Values are mean ± SEM

Age	Anxiety	Depression	BIS	BAS	Cigarettes per day	Years smoked
29.33 ± 9.33	1.18 ± 1.32	1.11 ± 0.47	3.43 ± 0.22	3.47 ± 0.24	22.83 ± 1.74	13.00 ± 8.50

Smoking questionnaire used in experiment 5.1 only

All data obtained during this experiment are confidential.

• What is your age? ……………

• Are you male or female? (please ring) Male / Female

• Which hand do you use for writing? Left / Right

• How many cigarettes do you typically smoke per day?

……………

• What time did you smoke your last cigarette? – Do not worry if you

it is critical that this information is accurate. Please specifiy the day, hour and minute.

……………

• For how many years have you smoked? ……………

• How soon after you wake up do you smoke your first Within 30 minutes

cigarette? After 30 minutes.

• Do you find it difficult to refrain from smoking in places where

it is forbidden, e.g. in church, at the library, in cinemas etc? Yes / No

• Which cigarette would you most hate to give up? The first one in the morning

Any other.

• How many cigarettes do you smoke per day? 15 or less

16-25

26 or more

• Do you smoke more frequently during the first hours after awakening than during the rest of the day? Yes / No

• Do you smoke if you are so ill that you are in bed for most of the day? Yes / No

• What is the nicotine level of your usual brand of cigarette? 0.9mg or less

1.0-1.2mg

1.3mg or more

• Do you inhale? Never

Sometimes

Always

• If you are a non-smoker, how many cigarettes have

you smoked in your lifetime? ……………

• To what extent do you find smoking unpleasant?

Not at all Extremely

unpleasant

I———————————————————————I

• Have you smoked cannabis in the past? ……………

• If yes, how many times have you smoked cannabis? ……………

• Do you currently smoke cannabis? ……………

• If yes, how many times do you smoke cannabis per week? ……………

Appendix 5 (experiment 6.1)

Likelihood to first fixation in aware participants for predictive stimuli (A, B, or C) on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
0.08 ± 0.06	0.05 ± 0.04	0.05 ± 0.05

Dwell time bias scores for unaware participants on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
0.18 ± 0.06	0.50 ± 0.28	0.06 ± 0.18

Likelihood to first fixation for unaware participants for predictive stimuli (A, B, or C) on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
0.10 ± 0.09	0.12 ± 0.04	0.02 ± 0.01

Expectancy ratings for unaware participants on AX, BX, and CX trials, collapsed across conditioning trials. Values are mean ± SEM

AX	BX	CX
5.83 ± 0.55	5.06 ± 0.27	5.45 ± 0.57

Anxiety ratings for unaware participants for A, B, and C stimuli, collapsed across conditioning trials. Values are mean ± SEM

A	B	C
3.72 ± 1.41	3.75 ± 1.74	2.13 ± 0.76

Affective value rating of the noise outcome for unaware participants, obtained prior to conditioning on a 1-9 Likert scale. Values are mean ± SEM

3.00 ± 1.15

Questionnaire variables for unaware participants obtained prior to conditioning. Values are mean ± SEM

Age	Anxiety	Depression	BIS	BAS
23.33 ± 2.03	0.52 ± 0.30	0.78 ± 0.55	3.14 ± 0.30	3.40 ± 0.16

Number of responses made for unaware participants during the instrumental conditioning phase for AX, BX, and CX trials, collapsed across trials. Values are mean ± SEM

AX	BX	CX
2.14 ± 0.70	2.73 ± 0.98	2.09 ± 0.66

Appendix 6 (questionnaires used in experiments 2.1 to 6.1)

a) Medical history questionnaire

Nuffield Hospitals Medical History Questionnaire

Confidential Sub no. ....

Please complete all sections of this

form unless otherwise indicated.

Medical History Questionnaire

Name (Full)...

Date of Birth.................. Sex.......... Height................... Weight...................

Please underline the appropriate answer where a **'Yes'** or **'No'** is required. If your answer is **'Yes'** brief details should be given.

1. Have you suffered from any of the following?

		Details
Diabetes Mellitus	**Yes / No**	
Epilepsy	**Yes / No**	
Frequent chest, throat or nose infections/diseases	**Yes / No**	
Back injury/backache	**Yes / No**	
Joint injury	**Yes / No**	

Ear infection	**Yes / No**
Rheumatism or Rheumatic fever	**Yes / No**
Urinary problems or kidney disease	**Yes / No**
Infectious diseases (Mumps, Measles, German Measles, Tuberculosis etc.)	**Yes / No**
Hepatitis	**Yes / No**
Heart disease	**Yes / No**
High blood pressure, chest pain, shortage of breath	**Yes / No**
Anxiety or Depression requiring treatment	**Yes / No**
Nervous breakdown or debility arising from overwork	**Yes / No**
Menstrual problems	**Yes / No**
Haemorrhoids	**Yes / No**
Dyspepsia or Peptic Ulcer	**Yes / No**
Hernia	**Yes / No**

Dysentry/Typhoid/Food poisoning	**Yes / No**
Any other stomach disorder	**Yes / No**
Varicose veins	**Yes / No**
Migraines or other frequent headaches	**Yes / No**
Hay fever, eczema or other allergies	**Yes / No**
Skin disorders	**Yes / No**
Fainting or giddiness	**Yes / No**
Poor eyesight (even when wearing glasses/contact lenses)	**Yes / No**
Please give date when eyesight was last tested (approx.)	**Yes / No**
Impaired hearing	**Yes / No**

---

2. Are you a registered disabled person? **Yes / No** If **'Yes'** what is you registration number and expiry date?

---

3. a) Have you been an in-patient in hospital or consulted your GP during **Yes / No** If **'Yes'** please give details:

the last five years?

b) How many days of sickness have you had in the last 12 months?		What were the main causes?
c) Are you taking any pills, tablets or having injections, receiving any medical or psychiatric treatment or advice or awaiting surgery?	**Yes / No**	If **'Yes'** please give details:

---

4. How often do you visit your dentist?

When was your last visit?

---

5. What was the date of your last immunisation against the following: (approx.)

Tetanus

Tuberculosis

Polio

Rubella (German Measles)
(Anti-D Gammaglobulin)

Hepatitis B

---

6. Date of last x-ray Reason for x-ray

---

7. General state of health; please comment on any aspects not covered above (i.e. accidents, injuries, disorders not mentioned).

8. What is your average consumption of (* A unit- single measure of spirit /one glass of wine/ half a pint of beer)

a) alcohol units* per week

b) tobacco per day

c) drugs number of days per month (please name each drug and list consumption separately for each one)

9. Is there any additional information regarding your health not covered in the above questions?

I declare that the answers given to the above questions are true to the best of my knowledge and I have not withheld any material facts which may have any bearing as to the state of my health.

Signature Date

b) POMS questionnaire

Please rate from 0= not at all to 4=extremely, how the different adjectives represent your current mood state

Not at all	A little	Moderately	Quite a bit	Extremely	
0	1	2	3	4	Friendly
0	1	2	3	4	Tense
0	1	2	3	4	Happy
0	1	2	3	4	Angry
0	1	2	3	4	Worn out
0	1	2	3	4	Unhappy
0	1	2	3	4	Confused
0	1	2	3	4	Lively
0	1	2	3	4	Unable to concentrate
0	1	2	3	4	Sorry for things done
0	1	2	3	4	Shaky
0	1	2	3	4	Listless
0	1	2	3	4	Overjoyed
0	1	2	3	4	Peeved
0	1	2	3	4	Agreeable
0	1	2	3	4	Sad
0	1	2	3	4	Active
0	1	2	3	4	On edge
0	1	2	3	4	Grouchy
0	1	2	3	4	Fatigued
0	1	2	3	4	Muddled
0	1	2	3	4	Blue
0	1	2	3	4	Energetic
0	1	2	3	4	Spiteful
0	1	2	3	4	Hopeless
0	1	2	3	4	Satisfied
0	1	2	3	4	Panicky
0	1	2	3	4	Helpful
0	1	2	3	4	Unworthy
0	1	2	3	4	Annoyed
0	1	2	3	4	Cheerful
0	1	2	3	4	Exhausted
0	1	2	3	4	Resentful
0	1	2	3	4	Forgiving
0	1	2	3	4	Discouraged
0	1	2	3	4	Relaxed
0	1	2	3	4	Bewildered
0	1	2	3	4	Sluggish
0	1	2	3	4	Uneasy
0	1	2	3	4	Kindly

Not at all	A little	Moderately	Quite a bit	Extremely	
0	1	2	3	4	Lonely
0	1	2	3	4	Miserable
0	1	2	3	4	Efficient
0	1	2	3	4	Bitter
0	1	2	3	4	Pleased
0	1	2	3	4	Alert
0	1	2	3	4	Ready to fight
0	1	2	3	4	Restless
0	1	2	3	4	Good-natured
0	1	2	3	4	Gloomy
0	1	2	3	4	Desperate
0	1	2	3	4	Rebellious
0	1	2	3	4	Nervous
0	1	2	3	4	Helpless
0	1	2	3	4	Weary
0	1	2	3	4	Elated
0	1	2	3	4	Forgetful
0	1	2	3	4	Deceived
0	1	2	3	4	Full of pep
0	1	2	3	4	Warm-hearted
0	1	2	3	4	Carefree
0	1	2	3	4	Furious
0	1	2	3	4	Uncertain about things
0	1	2	3	4	Worthless
0	1	2	3	4	Anxious
0	1	2	3	4	Vigorous
0	1	2	3	4	Terrified
0	1	2	3	4	Good-tempered
0	1	2	3	4	Guilty
0	1	2	3	4	Bushed
0	1	2	3	4	Bad-tempered
0	1	2	3	4	Refreshed

c) BIS/BAS questionnaire

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

1. A person's family is the most important thing in life.
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
3. I go out of my way to get things I want.
4. When I'm doing well at something I love to keep at it.
5. I'm always willing to try something new if I think it will be fun.
6. How I dress is important to me.
7. When I get something I want, I feel excited and energized.
8. Criticism or scolding hurts me quite a bit.
9. When I want something I usually go all-out to get it.
10. I will often do things for no other reason than that they might be fun.

11. It's hard for me to find the time to do things such as get a haircut.
12. If I see a chance to get something I want I move on it right away.
13. I feel pretty worried or upset when I think or know somebody is angry at me.
14. When I see an opportunity for something I like I get excited right away.
15. I often act on the spur of the moment.
16. If I think something unpleasant is going to happen I usually get pretty "worked up."
17. I often wonder why people act the way they do.
18. When good things happen to me, it affects me strongly.
19. I feel worried when I think I have done poorly at something important.
20. I crave excitement and new sensations.

21. When I go after something I use a "no holds barred" approach.
22. I have very few fears compared to my friends.
23. It would excite me to win a contest.
24. I worry about making mistakes.